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BRL

TECHNICAL NOTE NO. 1541

AUGUST 1964

KINEMATIC EVALUATION OF

THE SPECIAL PURPOSE INDIVIDUAL WEAPON PROTOTYPES (U)

Richard F. Cronin
Stanley S. Lentz
Wallace M. Werner

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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A B E R D E E N   P R O V I N G   G R O U N D ,   M A R Y L A N D

BALLISTIC RESEARCH LABORATORIES

TECHNICAL NOTE NO. 1541

RFCronin/SSLentz/WMWerner/rhg/mts/mrh
Aberdeen Proving Ground, Md.
August 1964

KINEMATIC EVALUATION OF THE SPECIAL PURPOSE INDIVIDUAL WEAPON PROTOTYPES (U)

(UNCLASSIFIED) ABSTRACT

The mechanics of three prototype weapons are compared and the conformance of the weapons to the Special Purpose Individual Weapon concept discussed. Testing procedures and results are included.

(UNCLASSIFIED) TABLE OF CONTENTS

(UNCLASSIFIED) INTRODUCTION

In December 1962, the Army Weapons Command sent proposals from ten manufacturing companies to the Ballistic Research Laboratories (BRL) to be evaluated for the Special Purpose Individual Weapon System (SPIW). Personnel of the Interior Ballistic Laboratory (IBL) evaluated the kinematics of the various proposed systems and recommended that prototype weapons be manufactured by Aircraft Armaments, Incorporated, and by Winchester Arms Division of Olin Industries. It was also recommended that further research be carried out on a proposed three-barreled, open chamber weapon firing three cartridges simultaneously of the XM144 or XM110 types. Later, an eleventh proposal was also received from Springfield Armory. As a result of the evaluations by several different groups, the Selection Committee chose the following companies: Aircraft Armaments, Incorporated (AAI), Harrington and Richardson (H&R), Springfield Armory (SPR), and Winchester (WIN), to each produce ten prototype weapons as presented in their proposals.

Early in March 1964, three prototype weapons from each of ~~the~~ four contractors were delivered to BRL for kinematic analysis and evaluation. An extensive series of tests ~~have been~~ were conducted ~~since that time~~ to furnish ~~the~~ data for selecting the prototype which would be most advantageous to develop for the SPIW system.

Initial tests of the three barreled Harrington and Richardson weapon showed that the system was hopeless: first, because of its excessive weight; second, because the mechanism could not be made to function; and third, because the three-projectile round produced extreme variations in velocity and excessive dispersion in the target patterns. As a result, the Harrington and Richardson system was withdrawn from the program and given no further consideration.

The Cal. 7.62mm automatic rifle M14 and Cal. 0.223 automatic rifle M16 were designated as control weapons and fired in the program to provide a comparison to the competitive systems. The kinematic analysis of each weapon system is included in the following order:

Cal. 7.62mm Automatic Rifle M14

Cal. 0.223 Automatic Rifle, M16

Aircrafts Armaments, Incorporated

Springfield Armory

Winchester Arms Division, Olin Industries.

The control weapons are described in the discussion of the methods and techniques used in testing the prototype weapons. The analyses of the prototypes follow under separate headings.

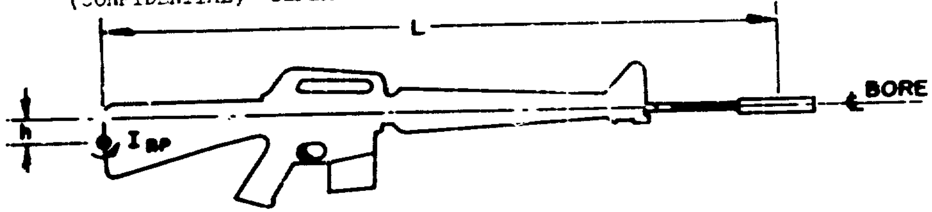
Considering that the main purpose of this report is to furnish guidance for selecting the best overall SPIW system, the report is arranged into three main sections. Section I includes comparative tables of average values such as weights, impulses, moments of inertia, cyclic rates, and overturning moment arms. Also included are comparative tables of malfunctions, problem areas, and a general assessment of the competitive SPIW systems. This should furnish a quick and ready reference for members of the Evaluation Committee. Section II includes a discussion of the testing methods and procedures, weapon operation, and analysis of the data. Section III presents information which documents those values given in the tables of Section I. Section IV contains a detailed series of tables showing the variations in the parameters of those weapons evaluated by IBL.

(CONFIDENTIAL) SECTION I. COMPARISON AND CONCLUSIONS (U)

Following are tables giving data for the prototype and control weapons as determined at IBL.

TABLE I

(CONFIDENTIAL) GENERAL WEAPON PARAMETERS (U)



	h	L	I_{BP} (lb ft sec^2) W/Rifle Loaded	I_{BP} (lb ft sec^2) W/Rifle & Launcher Loaded	Cyclic Rate (spm) 3 Rd Bursts	Cyclic Rate (spm) Full Auto	Impulse (lb sec) Recoil	Impulse (lb sec) Down	Impulse (lb sec) Left
	in.	in.							
AAI	2.90	39.00	0.217	1.714	2099	699	0.444	0.078	0.006
H&R	2.50	39.75	——	2.525	——	——	——	——	——
SPR	1.24	35.50	0.437	1.151	1670	1646	0.411	0.049	0.005
WIN	2.30	38.60	0.713	1.705	637	741	0.465	0.022	DNA
M14	3.97	42.75	1.054	DNA	760	747	2.632	——	DNA
M16	1.87	38.00	0.583	DNA	785	793	1.224	——	DNA
M16MBC	1.87	39.25	0.630	DNA	785	793	0.959	0.140	DNA

Symbols:

h = distance from center line of bore to center of butt plate
L = longitudinal distance from center of butt plate to center of muzzle device
I_{BP} = moment of inertia about the center of the butt plate
DNA = does not apply

TABLE II

(CONFIDENTIAL) WEIGHTS OF WEAPONS, COMPONENTS AND ACCESSORIES (U)

	Rifle Fully Loaded lbs	Rifle & Launcher Fully Loaded lbs	Rifle & Launcher Fully Loaded & Accessories lbs	Rifle W/O Foregrip W/Magazine lbs	Rifle Magazine lbs	Rifle Foregrip lbs	Launcher W/Magazine lbs	Launcher Magazine lbs	Bipod lbs	Sling lbs	Bayonet lbs
AAI	7.3	13.3	15.0	5.9	0.5	0.5	5.1	DNA	1.0	0.3	0.4
H&R	15.7	22.0	24.8	14.6	0.6	0.4	5.3	DNA	1.7	0.3	0.8
SPR	8.5	14.1	16.7	7.4	0.4	0.3	4.5*	0.5	1.1	0.2	0.6
WIN	8.0	12.5	15.1	7.0	0.8	0.2	3.2	DNA	2.0	0.2	0.4
M14	10.3	DNA	DNA	9.2	0.5	DNA	DNA	DNA	1.8	0.3	0.8
M16	7.0	DNA	DNA	6.5	0.2	DNA	DNA	DNA	—	0.3	—
M16MBC	7.1	DNA	DNA	6.6	0.2	DNA	DNA	DNA	—	0.3	—

* Single shot launcher = 1.91 lbs

DNA = does not apply

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TABLE III

(CONFIDENTIAL) WEIGHTS OF AMMUNITION (U)

	1 Pt. Fire Rd lbs	20 Pt. Fire Rds. lbs	60 Pt. Fire Rds. lbs	1 Area Rd. lbs	3 Area Rds. lbs
AAI	0.014	0.28	0.84	0.49	1.47
H&R	0.033	0.66	——	0.49	1.47
SPR	0.013	0.26	0.78	0.49	1.47
WIN	0.013	0.26	0.78	0.49	1.47
M14	0.054	1.08	3.24	——	——
M16	0.025	0.50	1.50	——	——

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TABLE IV

(CONFIDENTIAL) MALFUNCTIONS (U)

	Failure to Feed	Failure to Extract	Failure to Eject	Failure to Fire	Failure of 3 Rd Counter	Failure of Low Rate Mech.	Case Sp.	Mag. Jams	Total No. of Malfunctions	Total No. of Rds. Fired	Total No. of Trigger Pulls	Mal./Rd.	Mal./Trigger Pull
AAI	6	2	5	0	0	1	1	0	15	227	55	0.066	0.273
H&R	–	–	–	–	–	–	–	–	—	11	11	——	——
SPR	7	0	1	0	2	DNA	0	1	11	314	78	0.035	0.141
WIN	63	11	10	38	7	DNA	0	0	129	548	211	0.235	0.611
M14	0	0	0	0	DNA	DNA	0	0	0	50	9	0	0
M16	0	0	0	0	DNA	DNA	0	0	0	95	26	0	0

DNA = does not apply

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PROBLEM AREAS

AAI ------ (1) Ammunition must be lubricated and the chamber must be cleaned frequently to prevent case separations.

(2) Lubrication of ammunition produces excessive sludging of the mechanism and magazine.

(3) Either the friction should be reduced or the spring force increased in the magazine to position the round in a shorter time and prevent bolt overrides.

(4) The three-round selector may fail to function when exposed to dust, sand, and dirt because of its complexity and sludging.

(5) Extractor lip needs to be reinforced to prevent breakage.

(6) Quality control on ammunition is poor and causes widespread variation in impulse and functioning of weapon.

SPR ------ (1) Box magazine requires further development to obtain positive feeding.

(2) Extractor lip needs to be reinforced to prevent breakage.

(3) Backplate buffer system needs to be revised to eliminate cracking of operating rod-bolt carrier assembly and loss of the charging handle.

(4) A major redesign will be necessary if a low rate mechanism is required.

(5) Natural frequency of barrel and cyclic rate of the gun have a phase relationship which can increase the amplitude of the barrel vibration to the detriment of accuracy. This will most likely be maximum with prone-bipod firing.

(6) Plastic triggers should be reinforced to prevent breakage.

WIN ------ (1) Floating barrel does not give a significant decrease in the extreme spread of a three-round burst as compared to that of the locked barrel. If the floating barrel effect were maximized through redesign, the 5% level would not be obtained, except through use of compensation.

(2) The floating barrel concept produces most of the malfunctions encountered with the system.

(3) The recoil impulse of this weapon is the highest and the muzzle velocity is the lowest (WSL data).

(4) Normally, the weapon is underpowered.

(5) Firing pin lacks sufficient energy to fire the first round consistently. Sometimes even succeeding rounds fail to fire because of the relative motion of the barrel, receiver, and the firing pin.

(6) Magazine has excessive friction and lacks positive support for positioning the rounds in the feed throat.

(7) Fixed ejector adds excessive friction to the bolt and influences the rate of fire.

(8) Three-round burst control mechanism is weak and poorly designed.

(9) Weapon will fire upon charging unless the three round burst counter wheel is indexed.

(10) Muzzle attachment fails to hold the stripper securely.

(11) Extractor lip requires reinforcing to prevent breakage and the extractor spring requires redesign.

(12) The camming forces and torques during unlocking of the bolt are excessive.

Desirable Features

In reviewing the features of the three weapons, it appears that the best features might be combined advantageously into a single weapon. None of the three prototype weapons are capable of incorporating these features without extensive redesign. The desired features are as follows:

Stock, Butt Plate and Sights. Whatever the material used, the weapon should have a conventional drop stock with low sights for easy and accurate aiming. The line of thrust or the center line of the bore extended should be as near to the center of the butt plate as possible to avoid an overturning couple which tends to raise the muzzle. This is best accomplished by having the barrel and receiver placed as low as practical in the stock with much of the mechanism placed above the barrel. The stock of the Winchester weapon more nearly meets this requirement. The Aircraft Armaments weapon contains a drop stock and low sights but the line of thrust is above the heel of the butt plate, necessitating a large compensating force to limit muzzle rise. The Springfield version contains a straight stock with the line of thrust slightly below the heel of the butt plate, but the sights are high and aiming is awkward unless the butt plate rests high on the shoulder, on the extreme edge of the shoulder or on the muscles of the arm.

Three-Round Control and Mode of Fire Selector System. The selector and burst control should be simple, positive and rugged. It is desirable that it provide a low rate of fire for full automatic firing and automatic re-indexing for three-round burst control. The Springfield system most nearly meets these requirements. It has a cam method of operation of a combined three-round, full automatic and semi-automatic control unit which is durable but does not contain automatic re-indexing and low rate features. The Winchester control unit is inadequate. The Aircraft Armaments system performs all functions but is complicated and has relatively short endurance capabilities.

Selector Switch. The selector switch provided by Aircraft Armaments is advocated since it is easily set, accessible, and has good locking abilities. The Springfield selector switch is the most difficult to operate and most inaccessible of the three switches.

Magazine. The box type magazine is favored over the drum magazines because of its simplicity, ease of storage, ease of carrying, ease of field loading, and lower inherent friction.

Stripper Replacement. It should be possible to replace strippers with ease and speed. This is best provided for by the Winchester muzzle device.

Barrel. The barrel should be stiffened to increase its natural frequency of vibration and decrease its amplitude thereby reducing the influence of barrel movement on accuracy.

Bolt Mechanism. Some method should be devised to reduce the impact forces as the operating rod or bolt carrier cams and jerks the bolt rearward and jerks the cartridge case from the chamber. Such a method would contribute to the life of the extractor and reduce the possibility of case separations. This might take the form of a camming effect which breaks loose the case and provides the bolt with an initial velocity prior to the impact between bolt and bolt carrier. A second method which seems simpler is to install a relatively heavy spring between the bolt and bolt carrier which buffers their impact and eases extraction. Such an arrangement may be installed in any bolt mechanism assembly.

Ammunition. The conventionally primed round, XM144, is advocated since the multi-piece primed cartridge XM110 cannot be fired successfully without lubricating the case and the single piece primed cartridge XM190 provides marginal functioning when fired unlubricated.

(UNCLASSIFIED) SECTION II. METHODS OF MEASUREMENT AND ANALYSIS

Measurement

The weapons received for evaluation and comparison were as follows:

SYSTEM	NUMBER
AAI	2, 3, & 4
H&R	3, 5, & 7
SPR	11, 15, 19, 13, 14, & 17
WIN	1, 3, & 9
M14	608756 (TRW)
M16	030936 (COLT, AR-15, MOD. 02)

The study was concentrated upon the functioning of the mechanisms and the adequacy of their component parts, the effect of rate of fire and barrel flexibility upon accuracy, the weights of parts and combinations of components, the moments of inertia of various configurations and the components of impulse.

The pertinent measurements were made using the following techniques:

Displacement-Time Recordings, Mechanism. For the techniques of obtaining displacement-time records, BRL Report No. 610 should be consulted.

Each of the weapons was mounted in a machine rest by clamps as shown in Figure 1.

Figure 1. (UNCLASSIFIED) Mount for Bolt Motion Study

Firm rubber padding was used for protection. Reflectors were placed on the stock and on a convenient part of the operating rod. From the displacement-time records of these reflectors taken during three-round and ten-round bursts, the bolt motion can be inferred.

In this study, three three-round bursts and three ten-round bursts were scheduled for each of the weapons. The rates of fire were determined from the time between rounds. Representative cycles were selected from the records and the operating events of the weapon were identified by measuring the location of the part or parts of the mechanism. Figure 2 shows this for the M14 and M16.

The representative cycles were measured for displacement and time. Using differentiation formulas as presented in BRL Report No. 840, velocity versus time and acceleration versus time was obtained. The results were then plotted as shown in Figures 3 and 4.

The estimates of the accelerations associated with the impacts in the mechanisms were low due to the nature of the numerical analysis. These then were checked by graphical methods. Another check on the acceleration forces present was obtained by means of the displacement-time information and the calibration of the springs found in the mechanism. Further, with this information the energy of the firing pin at the time of primer contact could be estimated.

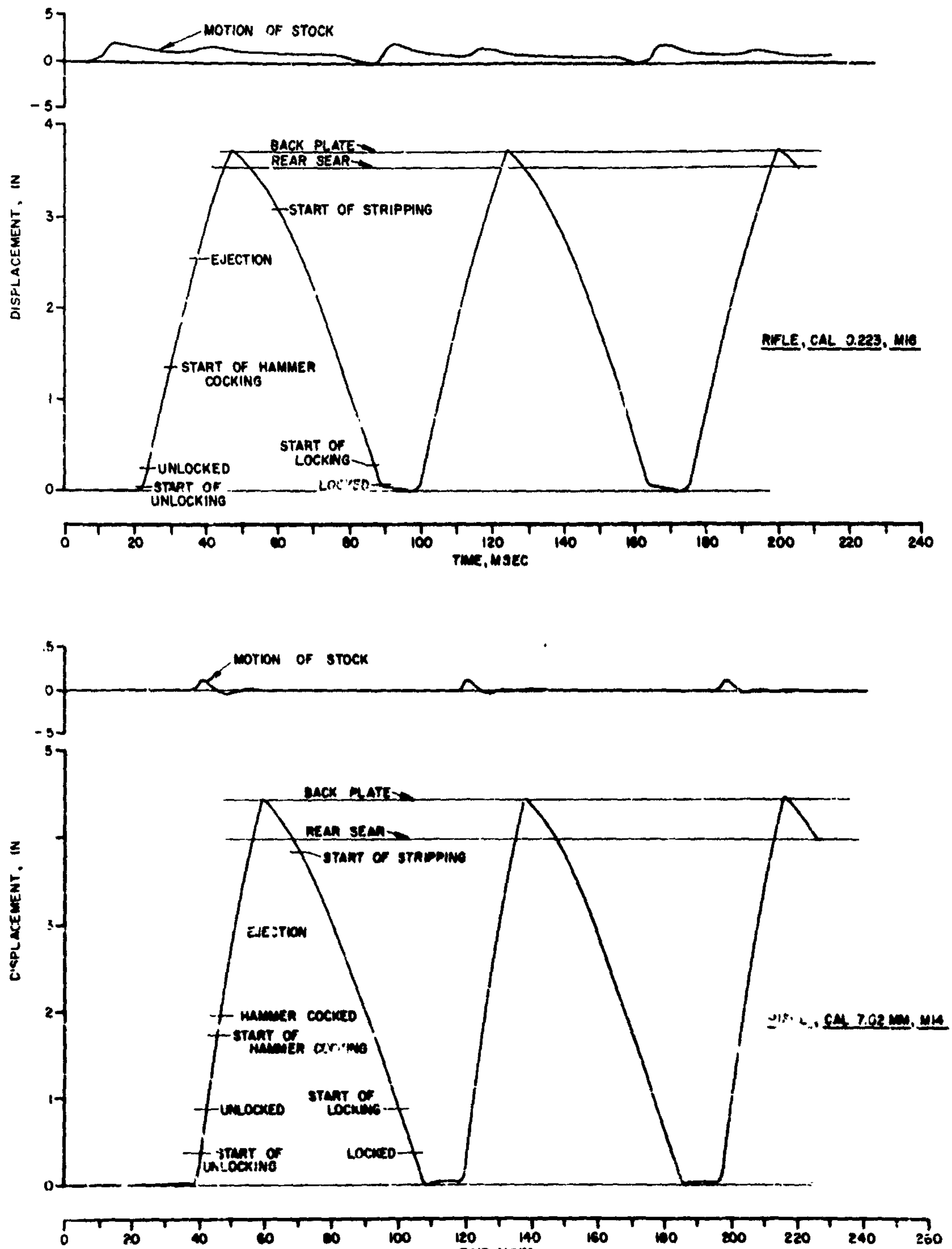
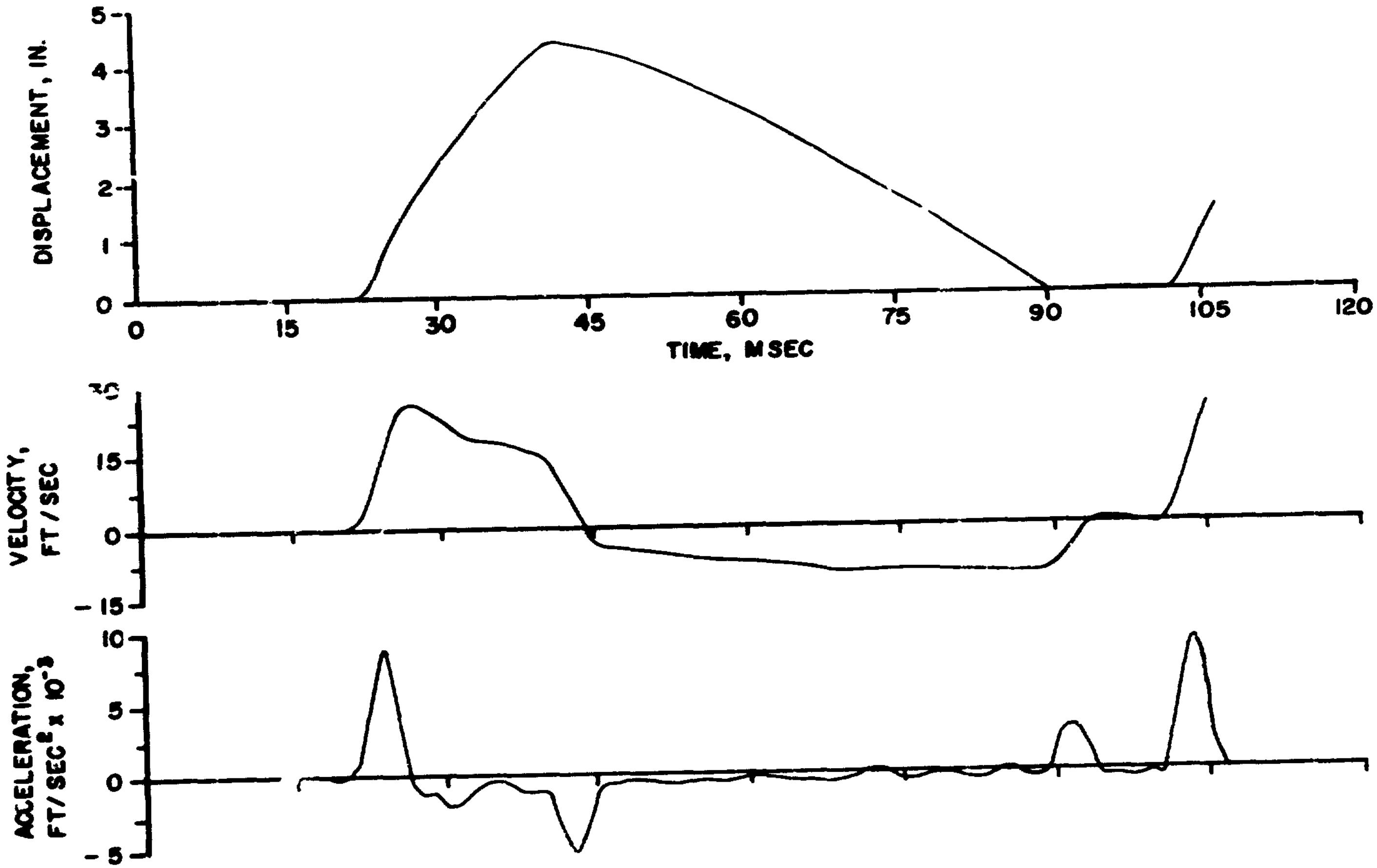
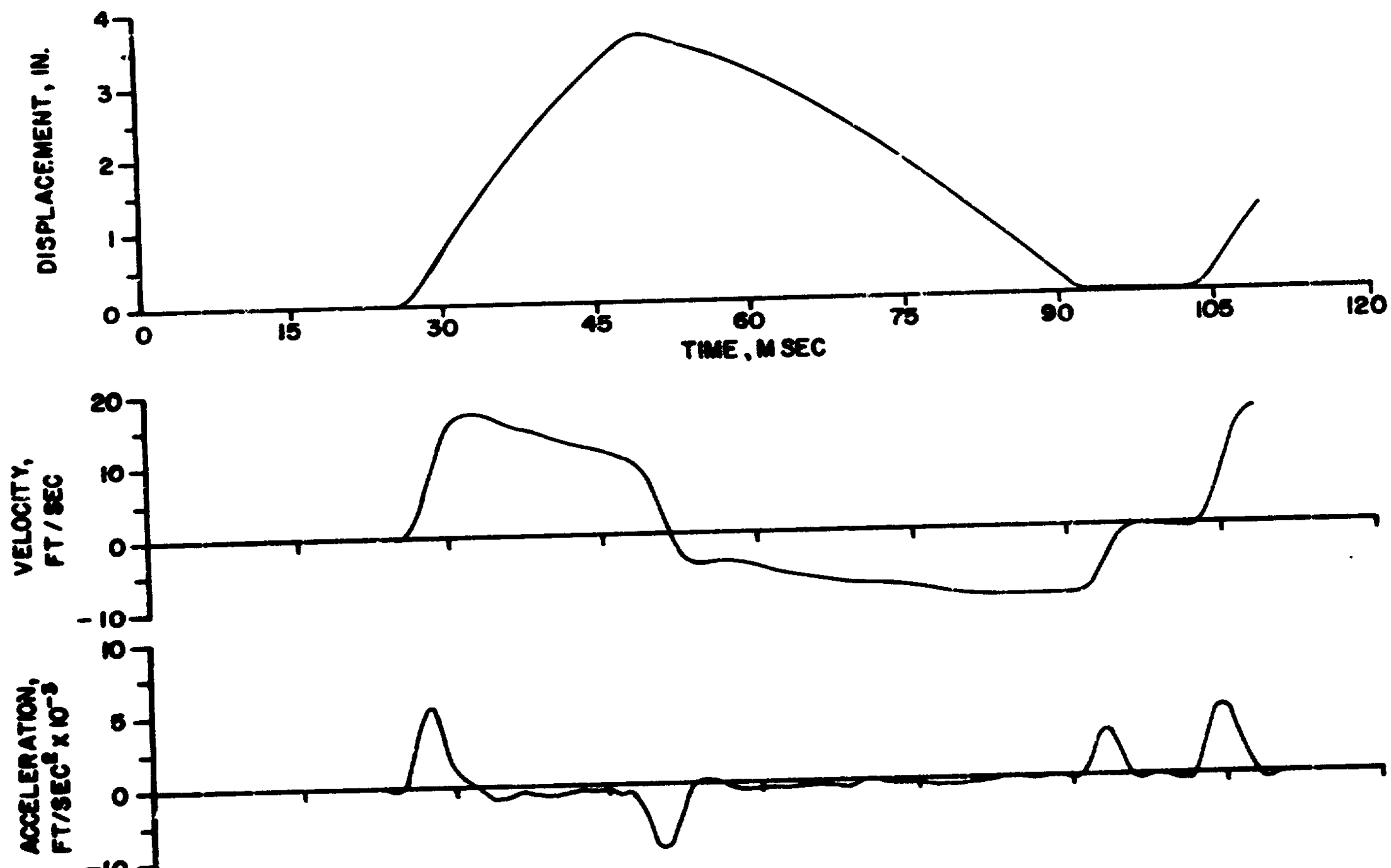


FIGURE 2 DISPLACEMENT vs. TIME
3 ROUND BURST



(UNCLASSIFIED) FIGURE 3 DISPLACEMENT, VELOCITY, ACCELERATION VS. TIME RIFLE, CAL. 7.62, M14



(UNCLASSIFIED) FIGURE 4 DISPLACEMENT, VELOCITY, ACCELERATION VS. TIME
RIFLE, CAL. 0.223, M16

Displacement-Time Recording, Muzzle. The weapons were fitted with reflectors on the muzzles such that the vertical oscillation of the muzzle could be obtained. The same weapon mounts were used as shown in Figure 1 except the forward support was moved back to the fore-grip as shown in Figure 5.

Figure 5. (UNCLASSIFIED) Mount for Muzzle Motions Study

Three three-round bursts and one area round were fired for each system. Displacement-time records obtained provided the basis for estimating the angle of the barrel at the muzzle. Targets were measured to provide a check on these estimates. Figure 6 shows records of the barrel motion for the M14, M16, and the M16 outfitted with a combination muzzle brake and compensator (MBC).

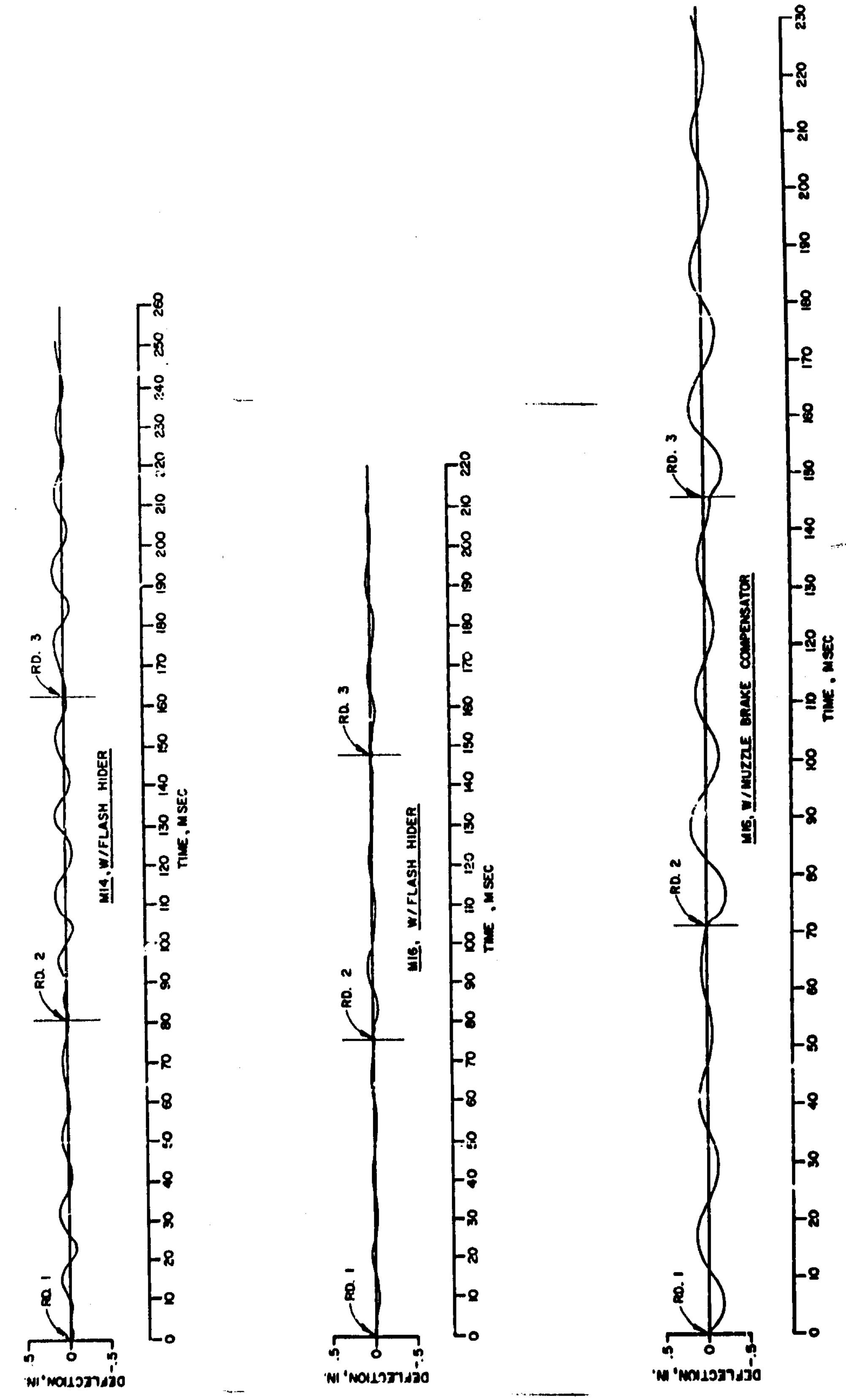


FIGURE 6 VERTICAL MUZZLE MOTION vs. TIME

The time of projectile emergence is recorded directly on the displacement-time record as fiducial lines. These are produced by the muzzle flash and the optics of the drum camera. The fiducial lines provide a means of determining rate of fire and the effect of the interaction of rate of fire and natural frequency of the barrel on target patterns.

Weights. The weights of components of the systems and of various combinations were determined by means of a balance scale.

Moments of Inertia. The moments of inertia of each weapon were determined by torsional pendulum techniques similar to those described in BRL Technical Note No. 874. The weapons were placed on a previously balanced tray which hung by a wire as shown in Figure 7.

Figure 7. (UNCLASSIFIED) Apparatus for Determining Moments of Inertia

The tray and weapon combination regains balance when the center of gravity of the weapon is vertically beneath the wire. A stylus, colinear with the wire, was used to mark the location of the center of gravity on the weapon. The torsional period of oscillation about the wire of the tray and weapon combination was measured. This leads to the value of the moment of inertia about the wire of the combinations. Subtracting the moment of inertia of the tray from this value gives the moment of inertia of the weapon about an axis parallel to the wire and through the center of gravity of the weapon. The moment of inertia about a parallel axis through the center of the butt plate is calculated from this value, the known weight of the weapon, and the distance of the center of gravity from the center of the butt plate.

Components of Impulse. The measurement of impulse is achieved by use of a ballistic pendulum. The techniques are described in BRL Memorandum Report No. 955. Each of the weapons was mounted in a three-wire pendulum, first on the side to measure recoil impulse and the component of impulse which is downward at the muzzle, and second, rotated 90° about the bore line to measure the recoil component and the leftward component of impulse at the muzzle. Ten rounds were fired for each of these two conditions. The technique was simplified for this study by placing a single stylus at the center of gravity of the pendulum bob and recording the motion of the bob on a horizontal surface as shown in Figure 8.

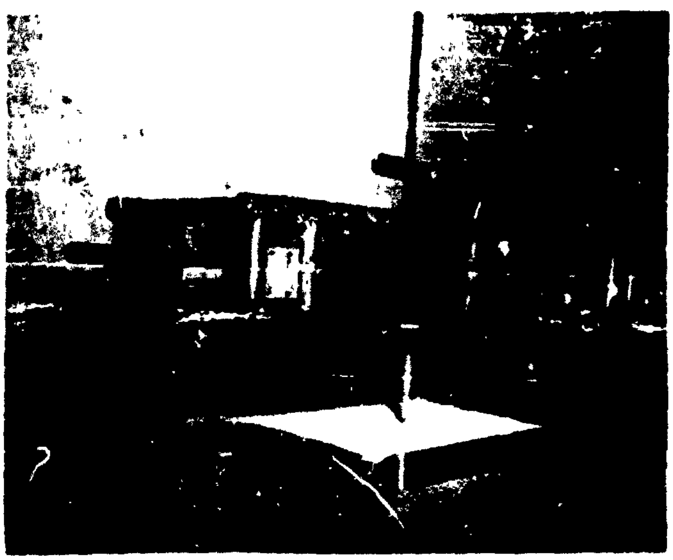


Figure 8. (UNCLASSIFIED) Weapon Mounted in Three Wire Ballistic Pendulum

The line drawn is parallel to the resultant impulse vector and its length is proportional to the magnitude of the vector. This test was carried out by the Development and Proof Service.

Analysis

Parts Life and Impacts. Impact forces, in general, are a measure of the life of the components in a weapon. The more severe the impacts sustained, the less the longevity that can be expected for the parts involved. The accelerations at impact at the breech, sear, unlocking and at the rear buffer can be transferred to any desired component of the bolt to estimate the force on that particular part. To obtain the accelerations and their corresponding forces, an average round of a burst was selected and the displacement-time record of that round differentiated to obtain both velocity and acceleration. Since the method of differentiation cannot handle discontinuities and is inaccurate for sudden changes of velocity in very short intervals of time, the acceleration has been estimated from the displacement-time curve by the tangent method.

Extraction. Since it is most difficult to estimate the force involved in extracting the fired case, i.e., the frictional forces between the case and chamber walls, the strength of the extractor must necessarily be a "cut and try" affair. At high rates of fire, the acceleration effects become much larger. Hence the extractors must be proportionally stronger as the rate increases; and the surface in contact with the rim is also proportionally increased.

Feed Mechanisms. Magazines should have a spring strong enough to raise a round to the feeding lips in the time allotted by the bolt. Feeding must be positive when one round is in the magazine or the magazine is full.

Ejectors. In general, an ejector which is fixed to the receiver instead of being a moving part of the bolt is more reliable.

Barrel Whip. The vibration of a barrel affects the accuracy of a weapon since the projectile is launched in accordance with the angle of the barrel at the muzzle and, to a lesser extent, the lateral velocity of the barrel at the time of projectile emergence. When barrels are relatively light and flexible and have muzzle compensators which provide lateral impulses to the barrel at the muzzle, the

magnitude of the oscillations can become large. In addition, when the weapon is fired automatically, the successive projectiles can emerge at times when the muzzle deviates considerably from the rest, aimed position. Further, the rate of fire of the weapon can be such that succeeding lateral impulses accentuate the oscillation remaining from previous rounds.

The rate of fire of the weapon can be chosen to be compatible with the natural frequency of the barrel but this arrangement will be lost if a bayonet and/or bi-pod is attached to the muzzle. It also will fail in so far as the rate of fire deviates from the optimum. In general, it is better to stiffen the barrel.

Whenever the weapon is fixed with respect to the ground in varying degrees of rigidity, the amplitude of the vibration and the accuracy of the weapon will vary according to the rigidity.

Problem Areas. In those cases where unusual or new problems arose with a weapon system, appropriate techniques were devised and are described in the section devoted to that weapon.

(CONFIDENTIAL) SECTION III: WEAPON SYSTEMS (U)

AIRCRAFT ARMAMENTS, INC. SPECIAL PURPOSE INDIVIDUAL WEAPON

Description

The Aircraft Armaments syste is shown in Figure 9. The point fire weapon is essentially gas operated, obtaining its energy for operation from the set back of a piston which is incorporated in the cartridge. In operation, the firing pin strikes the piston moving it forward to actuate the primer. The ensuing gas pressure accelerates the piston and firing pin rearward, unlocking the bolt with sufficient energy to cycle the mechanism at a rate of fire from 2000 to 2500 shots per minute in controlled three-round bursts. The mechanism also contains a selector which provides semi-automatic fire, three-rounds per trigger pull and full automatic fire. The rate of fire for full automatic fire is reduced to 600-750 shots per minute (SPM) by means of a time delay mechanism. The ammunition is fed into the rifle from a spring loaded, plastic drum magazine holding 60 rounds located immediately ahead of the trigger guard.

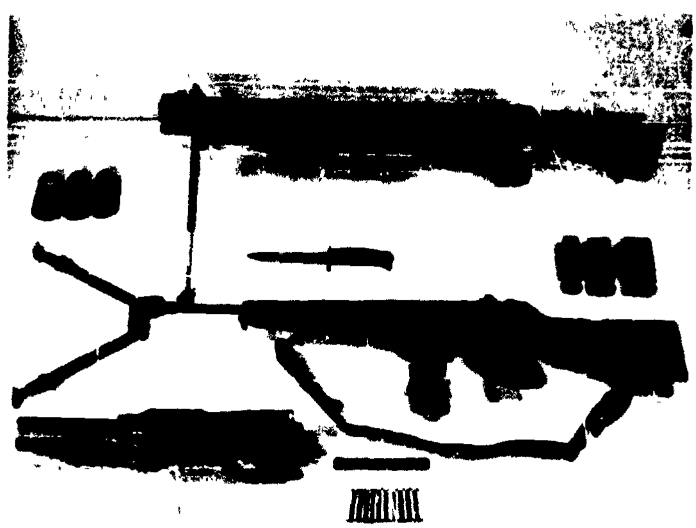


Figure 9. (CONFIDENTIAL) Aircraft Armaments SPIW System (U)

An area round launcher is attached to the stock beneath the barrel. The launcher holds three standard 40mm area rounds in a tandem magazine and is operated manually by lever action. The area round is fired by a trigger located beneath the launcher forward of the magazine of the point fire weapon. Rubber pads shown in Figure 10 are placed between the stock and area launcher to reduce the recoil force.

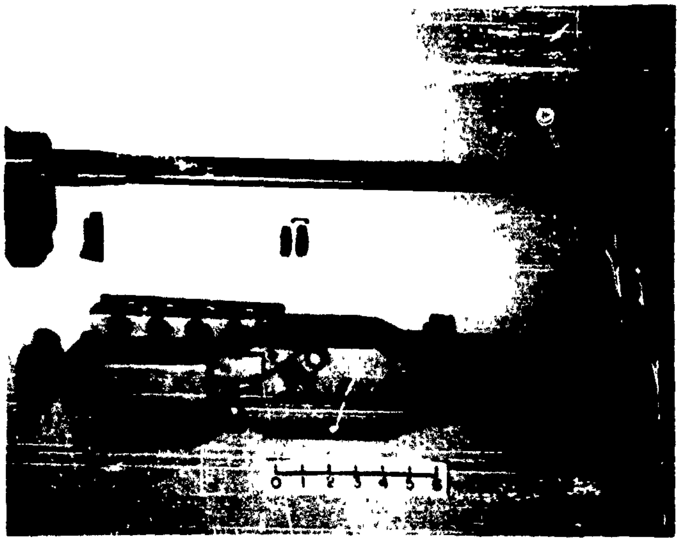


Figure 10. (CONFIDENTIAL) Launcher Recoil Pads (U)

The bolt assembly shown in Figure 11 is composed of the bolt body containing the extractor, locking cam and the locks, the firing pin containing the cam pin, the searing surfaces, the buffing surface, and the assembly which mates with and attaches the driving spring to the firing pin. Since the firing pin assembly serves the function of an operating rod it will be so termed. The driving spring, composed of two separate springs in parallel, also serves as the firing pin spring. A heavy spring buffer is assembled at the rear of the receiver to remove all remaining energy from the bolt assembly and return it to battery at a relatively high velocity.

Figure 11. (CONFIDENTIAL) Bolt, Firing Pin and Recoil Springs

Procedure and Results

Three rifles, No. 2, 3 and 4, complete with 40mm area round launchers were delivered for kinematic analysis and evaluation. Each of these weapons was mounted in the machine rest held at the rear by a butt support and boot backed up by the soft recoil pad on the rifle butt as shown in Figure 12. Displacement-time records of operating rod motion and barrel vibration were obtained. For barrel vibration the weapon was held as shown in Figure 13. Weapon No. 3 was also fired from the shoulder to observe vertical movement using the shoulder-elbow stance.

Figure 12. (UNCLASSIFIED) Mount for Bolt Motion Study

Figure 13. (UNCLASSIFIED) Mount for Muzzle Motion Study

A resumé of the firings with the three weapons together with the rates of fire and malfunctions are given in Table V.

TABLE V

(CONFIDENTIAL) FUNCTIONING DATA (U)

Aircraft Armaments, Inc.

Ammunition: XM110, Lot AAI-650-15

Weapon Number	No. of Rds. In Burst	Rate of Fire (spm) Max.	Av.	Min.	Remarks
		Three-round bursts, machine rest			
2					
	2	--	--	--	Failed to feed third round
	3	2459	2344	2230	
	3	--	--	--	Failed to feed, 12 o'clock stub
	3	2174	2035	1846	No rates taken, muzzle motion
	1	--	--	--	Failed to extract
	2	--	--	--	Failed to extract, broken extractor
	2	--	--	--	Failed to feed
	2	--	--	--	Failed to feed
		Changed to No. 3 magazine			
	3	--	--	--	
	3	--	--	--	
	3	--	--	--	
		Automatic fire, machine rest w/No. 3 magazine			
	10	714	697	688	
	11	714	701	696	Low rate mechanism failed on last round
	10	710	703	696	Failed to feed, round stuck in magazine throat
	10	713	701	690	
	10	710	700	696	

TABLE V (Cont'd)

Weapon Number	No. of Rds. In Burst	Rate of Fire (spm) Max.	Av.	Min.	Remarks
		Three-round bursts, machine rest			
3					
	3	2434	2320	2206	
	3	2338	2319	2299	
	3	2239	2207	2174	
		Three-round bursts, muzzle motion			
	1	--	--	--	Personnel error, semi-automatic setting
	3	--	--	--	
	3	--	--	--	
	3	--	--	--	
		Official demonstrations, no records			
					Broken extractor, replaced
					Check on extractor, shoulder fired
					1 Case separation
	28	--	--	--	4 Failures to eject
		Automatic fire, machine rest			
	10	694	687	681	
	10	731	691	676	
	10	715	685	657	
4		Three-round bursts, machine rest			
	3	1724	1709	1694	
	3	2047	2012	1976	
	3	1974	1913	1851	
		Three-round bursts, muzzle motion			
	2	--	--	--	Failed to load enough rounds
	3	--	--	--	Failed to eject third case
	3	--	--	--	
	3	--	--	--	Failed to eject th[illegible] 1 case

TABLE V (Cont'd)

Weapon Number	No. of Rds. In Burst	Rate of Fire (spm) Max.	Av.	Min.	Remarks
		Automatic fire, machine rest			
	12	916	766	686	Low rate mechanism failed on first and last rounds giving 1566 and 1538 spm
	8	860	741	679	
	10	729	684	587	
		711	705	696	
		Ammunition Lot 6002 fired for comparison Machine rest			
2	3	741	730	719	Failure of rear sear release
4	3	1923	1876	1829	Single crimp
	3	1993	1946	1899	Double crimp, low energy on last round
	3	2040	1788	1542	Double crimp, low energy on first round
	4	1714	1677	1608	Set for full automatic, low rate mechanism failed
		Ammunition Lot 650-14 fired for comparison Machine rest			
2	4	717	706	701	
	3	2190	2174	2158	
	3	2247	2243	2238	

A tracing of a three-round burst showing the salient points of functioning is shown in Figure 14.

The time delay mechanism which reduces the rate in full automatic fire is assembled at the rear of the selector mechanism. The delay element is composed of a spring loaded inertia wheel which, when struck by the operating rod toward its maximum travel, rotates the wheel. The operating rod is caught on a rear sear and is released by the impact of a protrusion on the inertia wheel as it returns and releases the sear. A tracing of a burst in automatic fire is shown in Figure 15.

Figure 16 gives displacement versus time, velocity versus time and acceleration versus time of a typical cycle from a three-round burst.

The vertical motion of the muzzle was recorded when firing from the machine rest and from the shoulder-elbow position. The motion of the muzzle was obtained when firing both point target and area target rounds. Tracings of the records obtained are shown in Figure 17.

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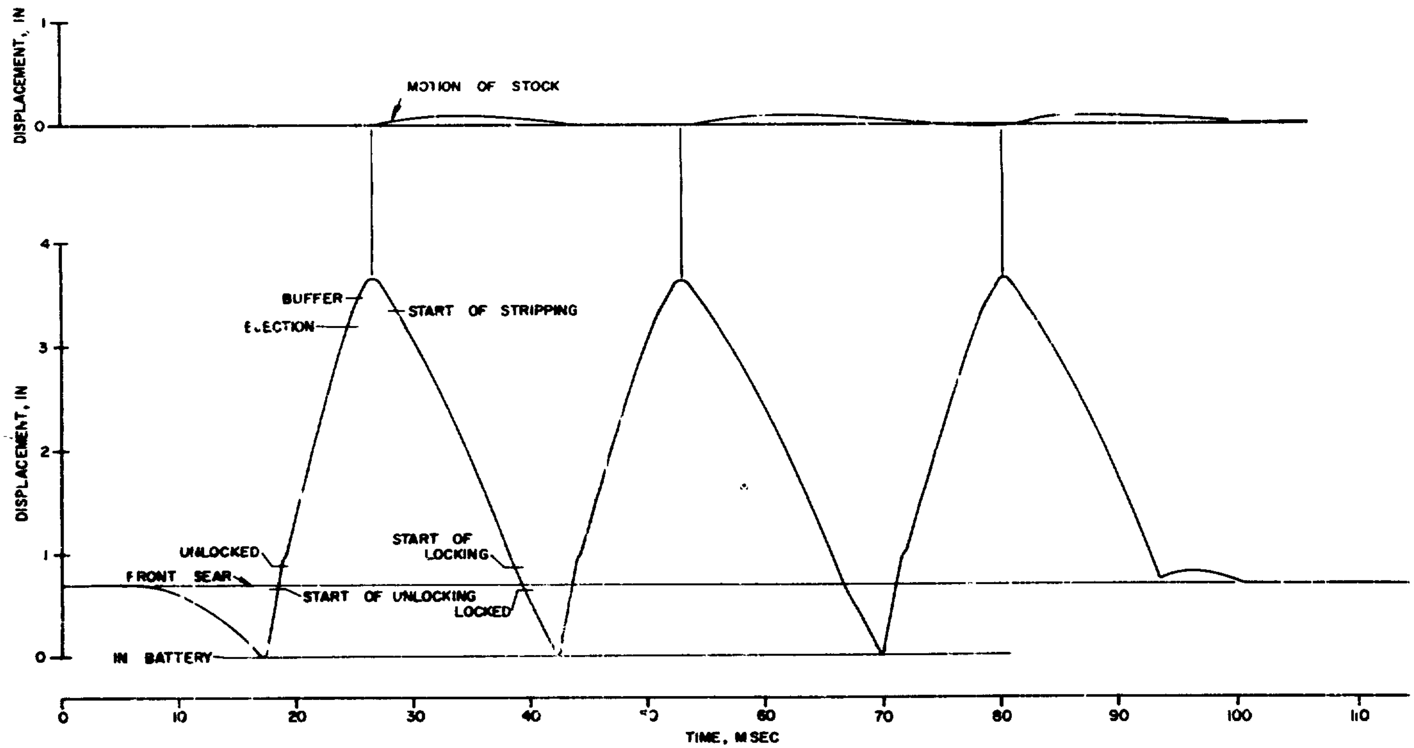

(CONFIDENTIAL) FIGURE 14 DISPLACEMENT VS TIME
CONTROLLED THREE-POUND BURST (U)
AIRCRAFT ARMAMENT, INC SPIW SYSTEM

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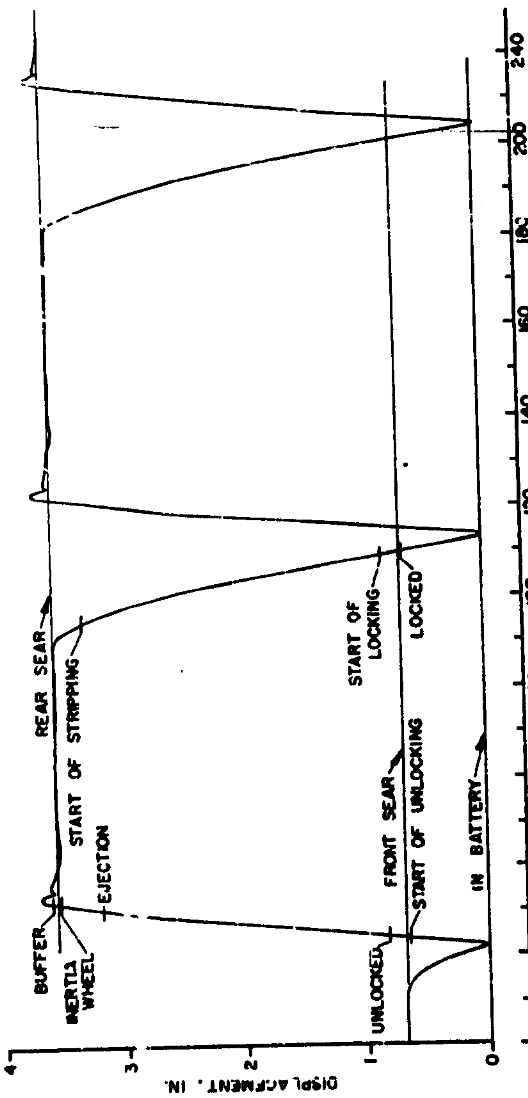
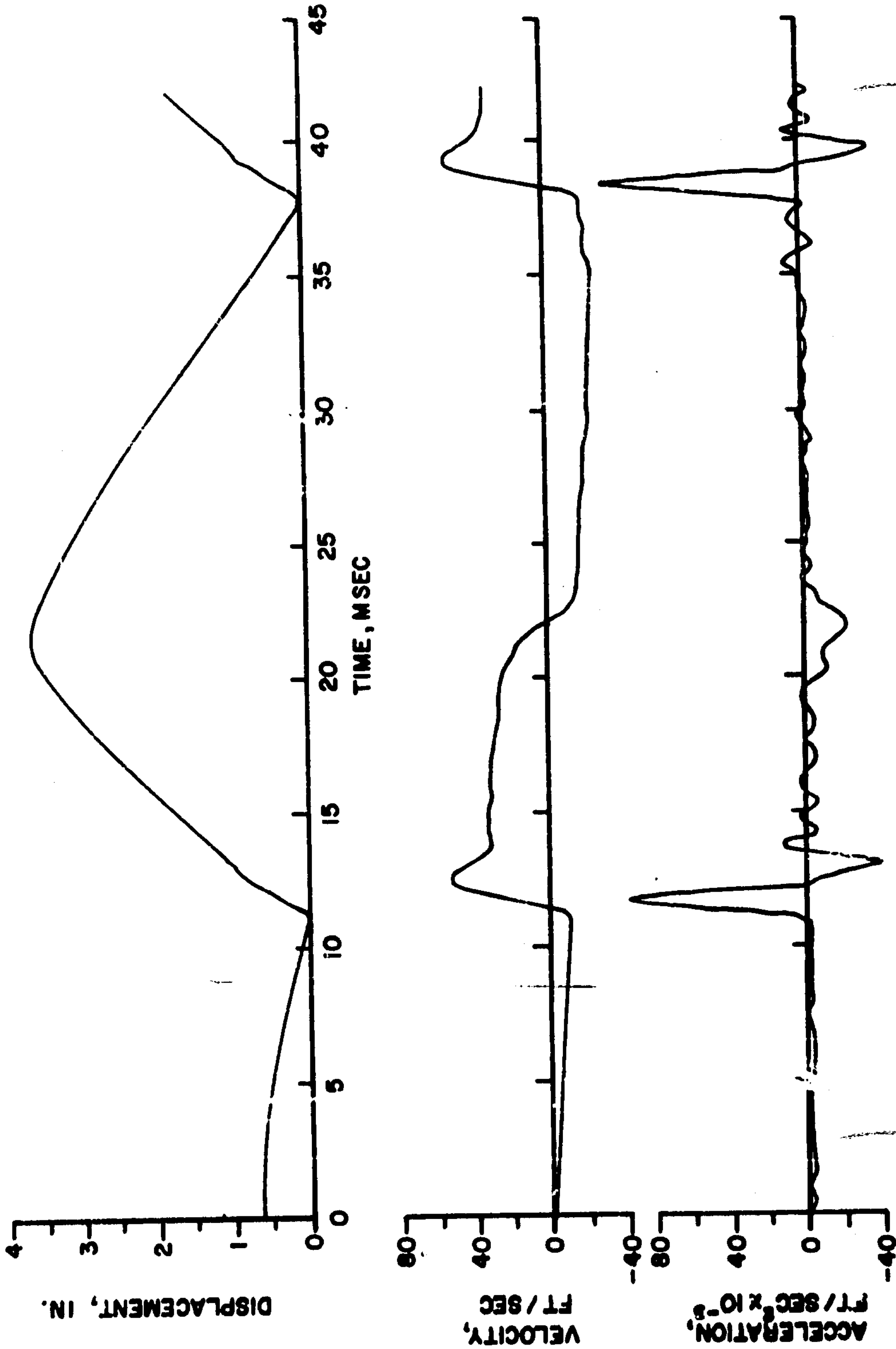
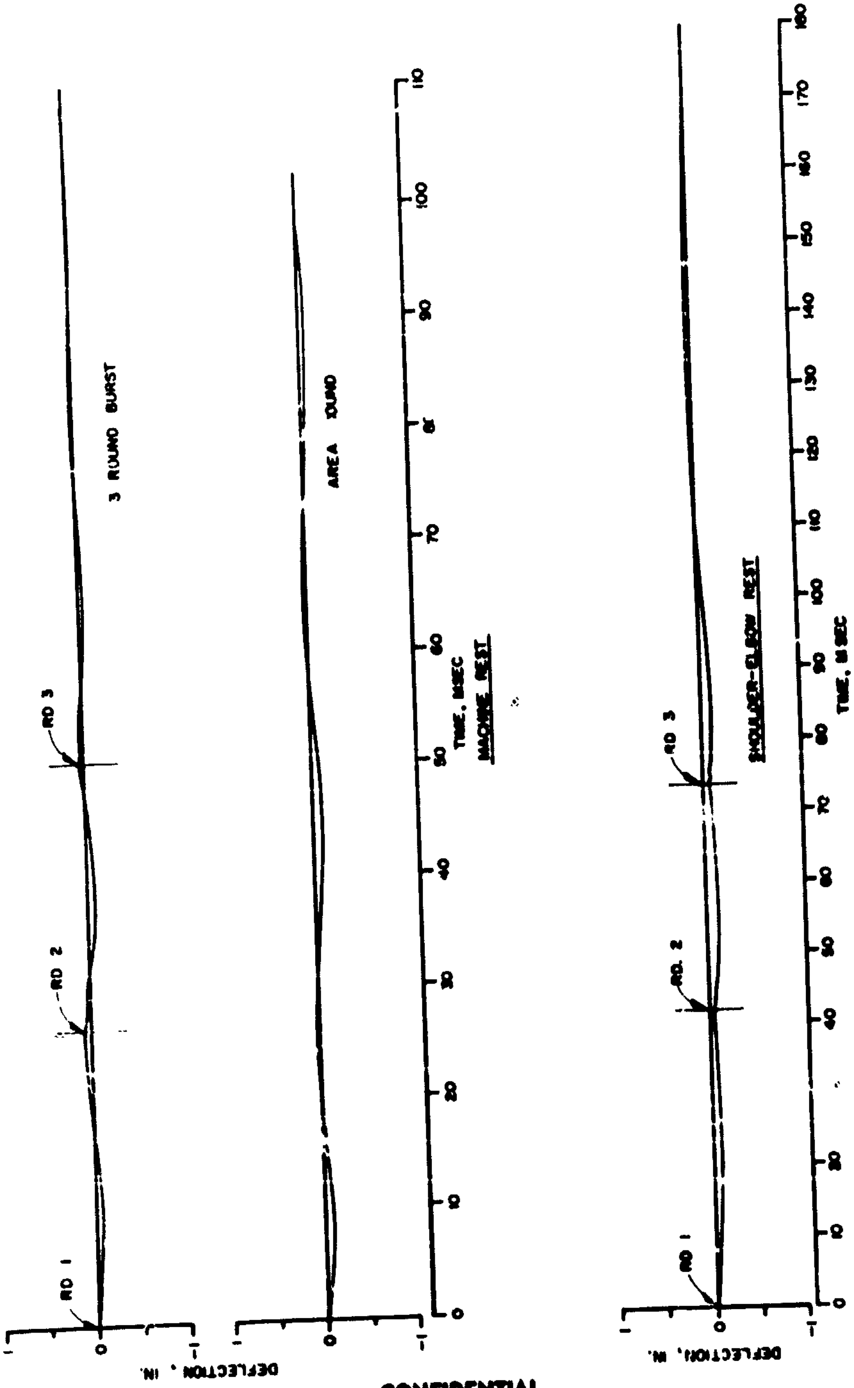


(CONFIDENTIAL) FIGURE 15 DISPLACEMENT VS TIME W/LOW RATE MECHANISM (U)
AIRCRAFT ARMAMENT, INC. SPIW SYSTEM



(CONFIDENTIAL) FIGURE 16 DISPLACEMENT, VELOCITY, ACCELERATION VS. TIME (U)
AIRCRAFT ARMAMENTS, INC. SPIW SYSTEM



(CONFIDENTIAL) FIGURE 17 VERTICAL MUZZLE MOTION VS. TIME (U)
AIRCRAFT ARMAMENTS SPIW SYSTEM

The motion of the muzzle was correlated with the position of the round impacts on the target. The vertical position of the rounds relative to the first round are quite similiar to the direction in which the muzzle is pointing at projectile emergence. However, due to the small angles involved and other possible factors the vertical distances of the impacts with respect to the first round are different from the distances calculated by radian measurement from muzzle motion assuming that the muzzle vibrates as a cantilever beam. The correlation of muzzle movement with target impacts is shown in Table VI.

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TABLE VI

(CONFIDENTIAL) VERTICAL BARREL DEFLECTION AND TARGET IMPACT (U)

AIRCRAFT ARMAMENTS, INC.

AMMUNITION: XM110, LOT AAI-650-15

Weapon No.	Av. Rate of fire (spm)	Barrel deflection (in.) 1st Rd	Barrel deflection (in.) 2nd Rd	Barrel deflection (in.) 3rd Rd	Target (in.) at 61 ft. 1st Rd	Target (in.) at 61 ft. 2nd Rd	Target (in.) at 61 ft. 3rd Rd	Barrel Frequency (Cycles/sec)	Firing Frequency (Shots/sec)	Ratio Firing Frequency / Barrel Frequency
2	2360	0	+0.03	+0.01	0	+1.4	+0.3	30.2	39.3	1.3
	2340	0	+0.04	+0.02	0	-1.2	+0.2	28.1	39.3	1.4
3	2400	0	+0.08	+0.03	0	+3.6	+2.3	30.0	40.0	1.3
	2330	0	+0.08	+0.03	0	+2.9	+1.8	29.3	38.8	1.3
4	1890	0	0	-0.06	0	+0.1	+3.6	30.2	31.4	1.04
	2140	0	+0.05	+0.12	0	+2.3	+6.1	30.3	35.6	1.2
	2140	0	+0.08	-0.03	0	+2.7	-7.0	29.4	35.6	1.2

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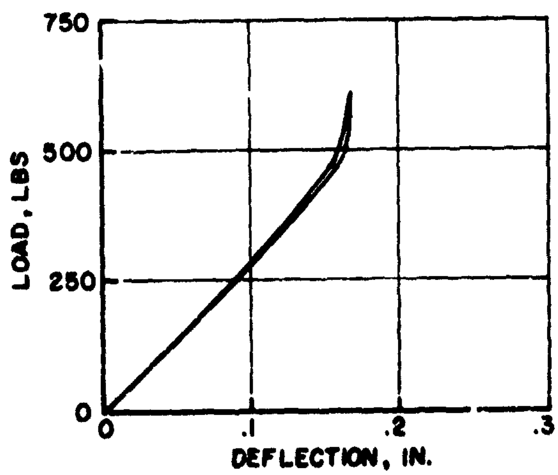
The impact loading between operating rod and buffer was estimated from the compression of the buffer spring obtained from the displacement-time record and from the load-deflection calibration curve of the buffer spring shown in Figure 18.



(UNCLASSIFIED) FIGURE 18 LOAD--DEFLECTION CURVE
BUFFER SPRING
AIRCRAFT ARMAMENT, INC. SPIW SYSTEM

The estimated acceleration forces occuring at several points in the bolt cycle are given as follows:

	Acceleration ft/sec^2	Force lbs
Operating rod-front sear impact	11.0×10^4	780
After primer ignition	22.8×10^4	-
Impact on buffer	----	350

The firing pin energy for firing a first round was computed from the weight and the final velocity measured from the displacement-time records. The average energy measured is 70 ± 6 inch-ounces. The average firing pin energy for other rounds of a burst is 100 ± 8 inch-ounces. No misfired rounds have been observed during the firings of this weapon system at IBL.

The acceleration forces at locking and chambering of rounds were not measured because the motion of the firing pin was recorded rather than the motion of the bolt. The force of acceleration at unlocking and extraction of the fired case may be obtained from the deceleration shown in Figure 16 and by assuming that the friction between the chamber and the cartridge case is zero. This assumption produces a minimum force. The acceleration force at unlocking is estimated to be 440 lbs. The extractor is also subjected to the same acceleration at unlocking but since the friction between the cartridge case and chamber walls is unknown, the force exerted on the extractor can not be estimated.

Discussion

In general the Aircraft Armament weapon functioned well. Discussion of the component mechanisms follows.

Mode of Fire Selector Mechanism. The selector mechanism is composed of the trigger, safety, sears, three-round counting device, low rate mechanism and selector switch as shown in Figure 19. This involves many small parts, some quite intricate. This mechanism can be removed and replaced as a unit. The three-round control consists of a twin cog escapement operated by the operating rod which allows three rounds to be fed into the chamber. After the third round is fired the escapement is returned to its original position by a spring if the trigger is released.

Following three-round bursts can be fired only by releasing the trigger. Thus the escapement has the facility of being indexed for three-round burst whenever the selector switch is shifted from full automatic or semi-automatic to a three-round burst setting.

Figure 19. (CONFIDENTIAL) Mode of Fire Control Mechanism (U)

The low rate mechanism is composed of an inertia wheel and clock spring. When the operating rod is near its maximum recoil, it hits a projection on the wheel. The wheel rotates against the spring while the operating rod is held on the rear sear. Upon return, the inertia wheel releases the sear allowing the bolt to return to battery to repeat the cycle. The rate of fire is reduced by this time-delay mechanism from over 2000 shots per minute to approximately 700 shots per minute. The time-delay unit does not always operate, particularly when hard extraction produces short bolt travel. Based on past performance of the time-delay units of other weapons, its functioning is expected to be erratic and its life limited.

Feed Mechanism. The plastic drum magazine produces a slim silhouette and occupies little space for the number of rounds held. However, the magazines are difficult to load in the field, have a variable spring tension and have variable time of positioning the round in the feed throat. In those instances where failures to feed have occurred it is believed that the round positioning time is less than the time allowed for positioning by the bolt. Additionally, the drum feed throat is directly under the breech of the gun. All of the carbon, smoke and oil from the oiled rounds is fed directly into the feed drum. This situation creates excessive friction in the magazine and may have some effect on extraction because of carbon particles adhering to cartridge cases.

Ejector. The ejector is fixed with respect to the receiver and should be quite positive in operation. However, six failures to eject were noted with gun No. 3. No definite opinion is formed as to the cause of the failures to eject.

Extractor. The extractors in the three weapons fired appear weak. Several have been broken and replaced and several failures to extract other than caused by a broken extractor have occurred. Because of the high acceleration at case extraction and the configuration of the components of the bolt, the extractor must be unusually strong to endure.

Chamber. The Aircraft Armaments rifle seems to be quite succeptible to dirt on the walls of the powder chamber. The accumulation of dirt causes case separation, hard extraction and undue strain on the extractor. Because of the short time from ignition of the primer to beginning of extraction, excessive amounts of powder gas residue are blown back from the bore requiring frequent cleaning of the powder chamber.

Barrel Whip. The vertical vibration of the barrel during firing when held more or less rigidly in a machine rest is considerable. When firing from the shoulder-elbow rest position the motion still persists. The compensator, placed at the muzzle to reduce the tendency of the weapon to move upward when fired from the shoulder, causes the barrel to bend and vibrate under the relatively strong downward thrust of the escaping powder gas.

Resumé

The Aircraft Armaments SPIW system uses a conventional drop stock with the operating mechanism high in the stock and low sights for easy aiming. The barrel is short with a relatively short portion unsupported. The muzzle compensator

causes excessive bending and vibration of the unsupported portion of the tube when the weapon is held more or less rigidly. The weapon, because of its primer piston operation, has a simple in-line bolt which makes it best able to withstand the high accelerations imposed by its high rate of fire. The weakest component of the bolt found to date is the extractor which is too lightly constructed to withstand the effects in extracting cartridge cases which at times may be difficult. The three-round control system is a relatively complicated escapement movement which may not have long endurance qualities. The control system contains an automatic reset to fire three-round bursts whenever the selector switch is so set. The plastic drum magazine appears unable at all bolt velocities to position the incoming round for feeding, either because of low spring tension or accumulation of dirt. Except for the three-round control system and the flexible barrel the weapon appears sufficiently rugged for military use.

(CONF.) SPRINGFIELD ARMORY SPECIAL PURPOSE INDIVIDUAL WEAPON (U)

Description

The Springfield Armory weapon is a conventional gas operated mechanism firing the conventionally primed XM144 cartridge. The system is shown in Figure 20.

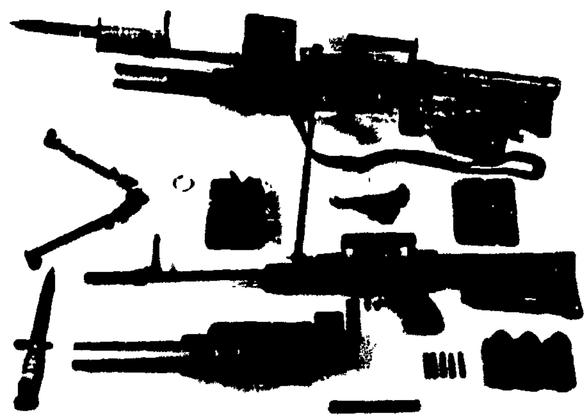


Figure 20. (CONFIDENTIAL) Springfield Armory SPIW System (U)

The main portions of the operating mechanism are housed in the rifle stock The weapon is equipped with a selector switch enabling it to fire semi-automatically, controlled bursts of three-rounds and fully automatic. The weapon contains no rate reducing mechanism and fires both automatic fire and controlled three-round bursts at the rate of 1500 - 1750 shots per minute. A muzzle-brake-compensator is used to reduce muzzle climb and dispersion. Ammunition is fed to the gun from a sixty-round box type magazine located behind the pistol grip and trigger guard.

The launcher is mounted beneath the barrel and is attached rigidly to the barrel guard which is an integral part of the stock. The launcher is automatically operated by blow-back and fires a 40mm area round fed from a three-round box magazine. Area rounds are fired by a separate trigger located immediately ahead of the rifle trigger. A single round launcher, designed to replace the automatic or three-round launcher, was also supplied. This launcher brakes and pivots for right hand loading as shown in Figure 21.

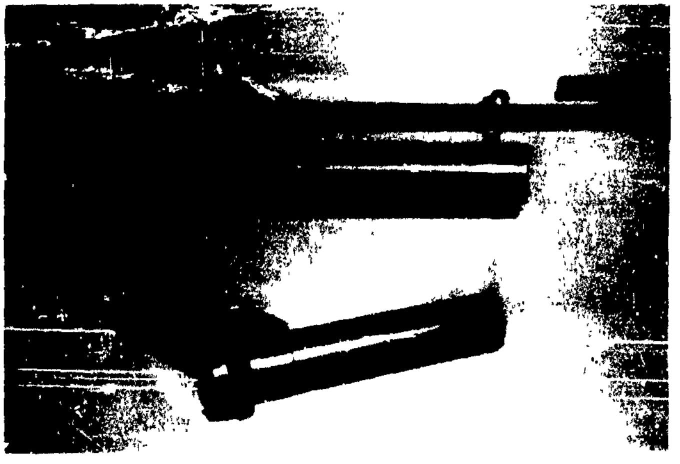


Figure 21. (CONFIDENTIAL) Single Shot Launcher (U)

The bolt which contains a splined rotating head is rotated and locked by a pin riding in a cam cut into the bolt body. The moving parts are shown in Figure 22. The bolt body is enclosed in a bolt carrier which is an offset and an integral part of the relatively ng operating rod. The operating rod is actuated by a short gas piston which unlocks and accelerates the rod and bolt rearward compressing the driving spring. At the rear of its stroke, a part of the operating rod which projects rearward roughly along a line parallel with the bottom of the operating rod hits a ring mounted on a strong, coil spring buffer. At the same time part of the bolt assembly travels rearward and impacts the lower portion of the buffer ring. The driving spring becomes the firing pin spring on both the first round and succeding rounds of a burst.

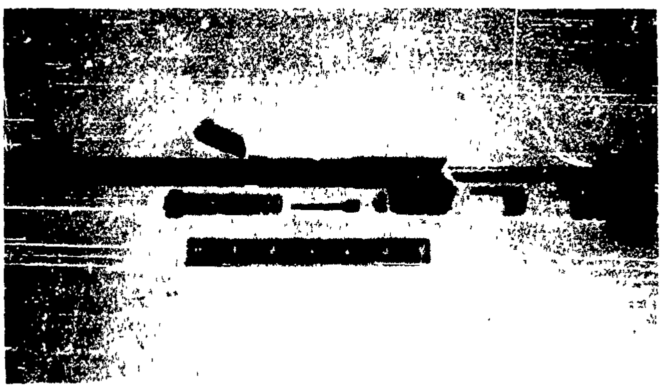


Figure 22. (CONFIDENTIAL) Bolt, Operating and Buffing Mechanism (U)

Proceaure and Results

Initially, three rifles were received for kinematic analysis, Nos. 11, 15 and 19. These rifles were mounted in a machine rest and fired to obtain displacement-time records of the operating rod and the rates of fire as shown in Figure 23. Prior to further firing these rifles were replaced with three different weapons, Nos. 13, 14 and 17. Between demonstrations, two of these weapons, Nos. 17 and 14, were fired for displacement-time records and rates of fire; and two, Nos. 13 and 14, were fired both in a machine rest and from the shoulder to obtain vertical muzzle motion, the effect of muzzle motion on dispersion, and the frequency of the barrel. For the shoulder-elbow position the muzzle motion was limited by vertical and horizontal members of a frame for safety and the camera focused as shown in Figure 24.

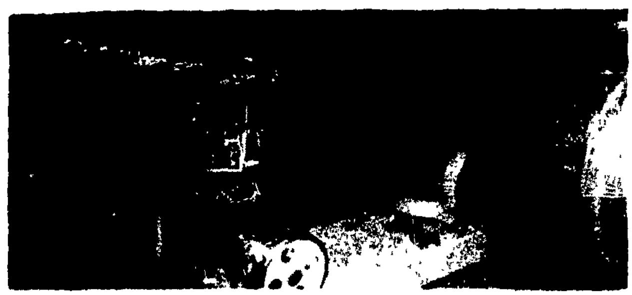


Figure 23. (UNCLASSIFIED) Mount for Bolt Motion Study

Figure 24. (UNCLASSIFIED) Soft Mount for Muzzle Motion Study

A tracing of a displacement-time record of bolt motion obtained from a three-round burst together with the salient points of interest occurring during a firing cycle is shown in Figure 25.

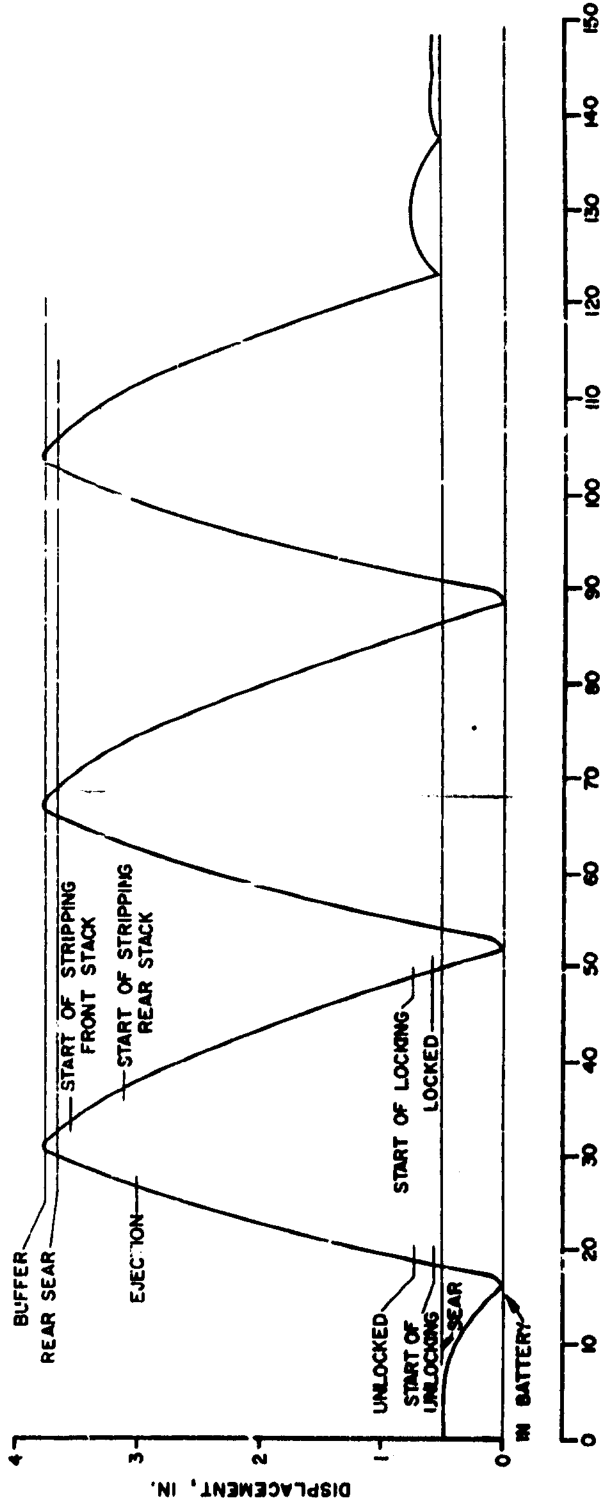
A record of the firings accomplished with the six Springfield weapons together with the rates of fire and kinds of malfunctions obtained are given in Table VII.

Tracings of the vertical motion of the muzzle obtained by point fire ammunition from the machine rest and from the shoulder-elbow position and the motion of the muzzle from firing a single area round are illustrated in Figure 26.

The vertical position of the muzzle at the approximate time of emergence of the projectile was measured and compared to the vertical distances of the impacts on the target using angular measurements. The results obtained are not accurate because of the assumed length of the vibrating barrel, inaccuracies in obtaining the exact time of emergence and the small angles involved. However, the order of the rounds and their impact on the target closely followed the position of the muzzle at emergence of the projectile. These values together with the frequencies of the barrel are given in Table VIII.

To obtain approximate values of velocity, acceleration and the forces involved during a firing cycle, a representative single round was selected from the displacement-time records and differentiated to obtain velocity and acceleration. The results of differentiating this record are shown in Figure 27.

Since the method of differentiating cannot handle discontinuities, all impact forces were computed from the change in velocity at the points interest by the tangent method. Since the values of acceleration and acceleration force did not always agree, the values of Figure 27 were used to estimate the unlocking force only. The acceleration forces at the breech and bolt sear were estimated from the tangent method; and the impact force on the buffer was estimated from the buffer



(CONFIDENTIAL) FIGURE 25 DISPLACEMENT VS. TIME
CONTROLLED 3 ROUND BURST (U)
SPRINGFIELD ARMORY SPIW SYSTEM

TABLE VII

(CONFIDENTIAL) FUNCTIONING DATA (U)

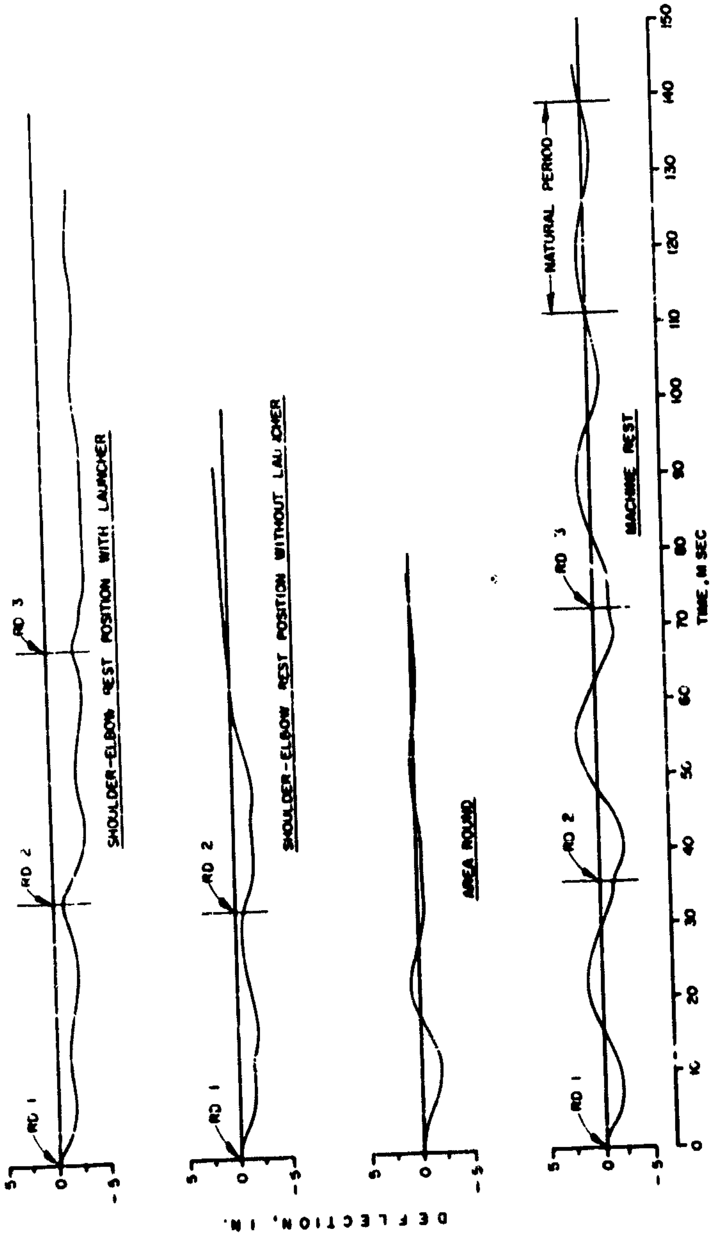
Springfield Armory

Ammunition: XM144, Lot WCC 6028

Weapon Number	No. of Rds. In Burst	Rate of Fire (spm) Max.	Av.	Min.	Remarks
11		Three-round bursts, machine rest			
	3	1661	1624	1587	
	3	1644	1619	1595	
	3	1646	1620	1594	
		Automatic fire, machine rest			
	8	1652	1590	1536	
	8	1635	1580	1540	
	11	1669	1614	1581	
15		Three-round bursts, machine rest			
	3	1714	1714	1714	
	3	1744	1678	1612	
	3	1721	1682	1643	
	3	1741	1736	1731	
		Automatic fire, machine rest			
	7	1842	1745	1696	Magazine jam, round from rear stack jammed between rounds in front stack.
	12	1802	1753	1691	
	11	1782	1723	1597	
19		Three-round bursts, machine rest			
	3	1675	1623	1571	
	3	1664	1629	1594	
	3	1736	1709	1672	
	3	1686	1639	1591	
		Automatic fire, machine rest			
	12	1653	1612	1577	
	12	1690	1662	1615	
	8	1670	1631	1545	Failure to feed, over ride.

TABLE VII (Cont'd)

Weapon Number	No. of Rds. In Burst	Rate of Fire (spm) Max.	Av.	Min.	Remarks
14		Three-round bursts, machine rest			
	3	1824	1708	1592	
	3	1646	1632	1619	
	3	1709	1679	1646	Failed to eject third case.
	6	1705	1640	1580	Selector failed, failure to feed, over ride.
	5	1717	1641	1583	Selector failed, failure to feed, over ride.
	2	--	--	--	Failure to feed, over ride.
		Automatic fire, machine rest			
	3	--	--	--	Failure to feed, 12 O'clock stub.
	9	--	--	--	Failure to feed, 12 O'clock stub. Magazine replaced.
	11	1782	1690	1613	
17		Three-round bursts, machine rest			
	3	1719	1637	1556	
	3	1724	1658	1591	
	3	1685	1657	1630	
	3	1734	1662	1579	
	2	--	--	--	Failure to feed, over ride.
		Automatic fire, machine rest			
	16	1724	1626	1550	
	8	1685	1606	1562	



(CONFIDENTIAL) FIGURE 26 VERTICAL MUZZLE MOTION VS. TIME (U)
SPRINGFIELD ARMORY SPIW SYSTEM

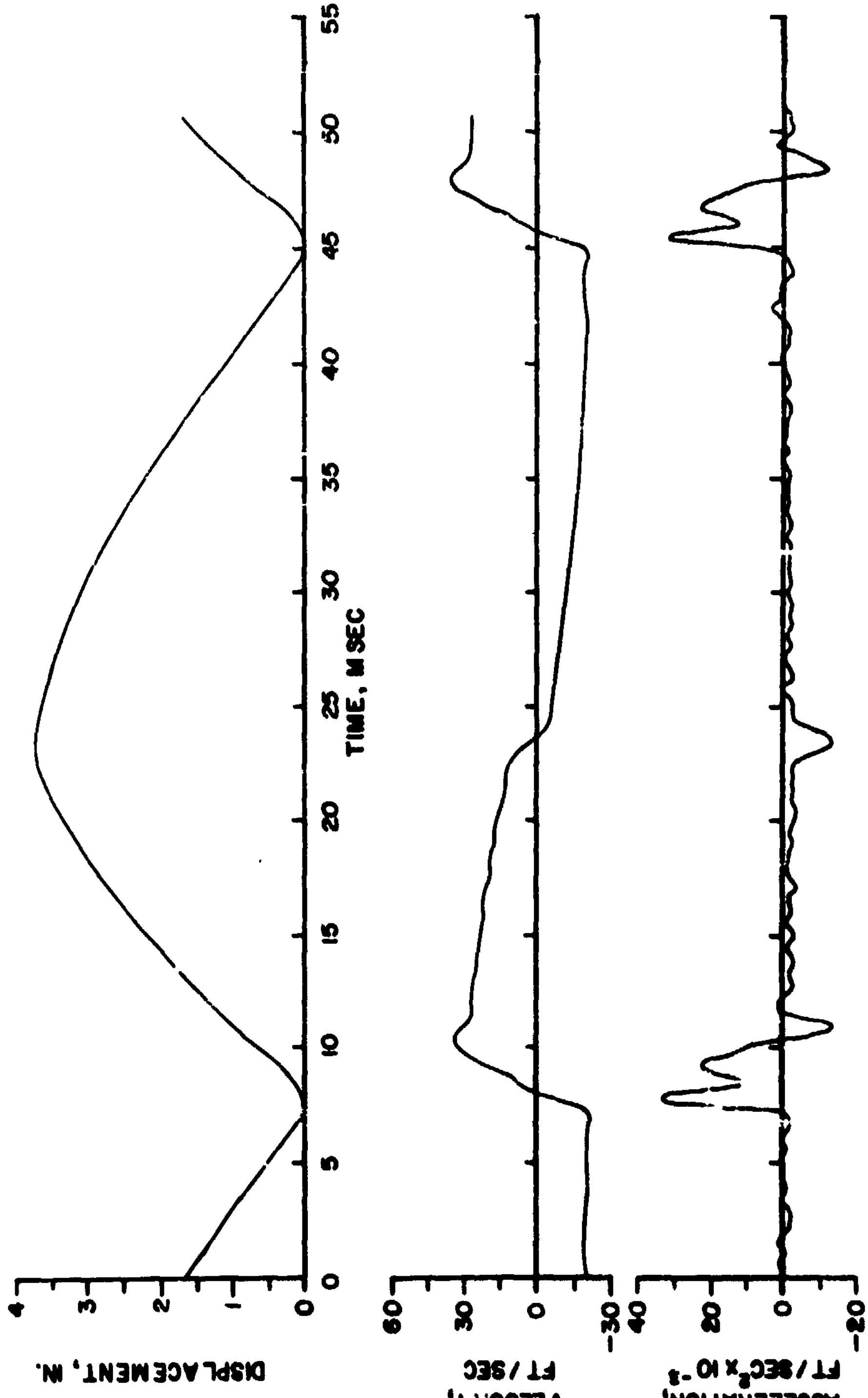
TABLE VIII

(CONFIDENTIAL) VERTICAL BARREL DEFLECTION AND TARGET IMPACT (U)

SPRINGFIELD ARMORY

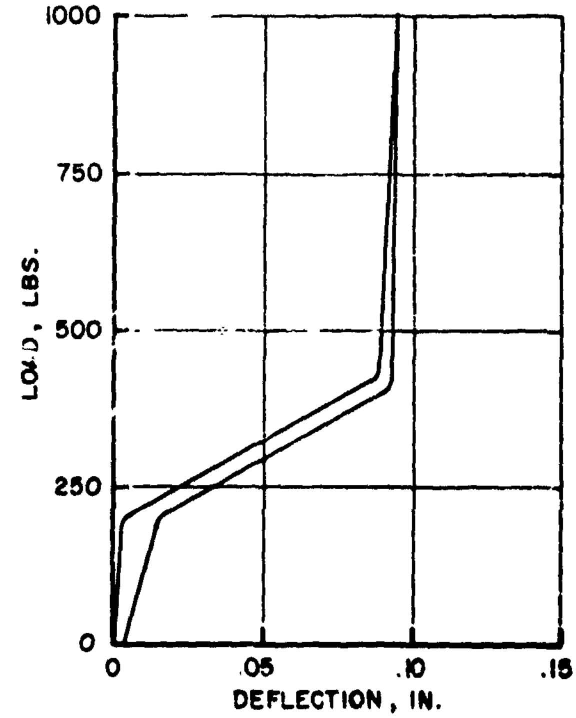
AMMUNITION: XM144, LOT WCC 6020

Weapon No.	Av. Rate of fire (spm)	Barrel deflection (in.) 1st Rd	2nd Rd	3rd Rd	Target (in.) at 61 ft. 1st Rd	2nd Rd	3rd Rd	Barrel Frequency (Cycles/sec)	Firing Frequency (Shots/sec)	Ratio Firing Frequency / Barrel Frequency
17	1694	0	-0.110	-0.150	0	-8.1	-9.2	35.7	28.2	0.80
	1560	0	-C.071	-0.110	0	-7.0	-8.5	35.1	27.8	0.79
14	1664	0	-0.118	-0.174	0	-8.8	-10.8	35.7	28.8	0.76
	1671	0	-0.102	-0.150	0	-7.2	-8.1	35.7	28.8	0.76
SHOULDER-ELBOW FIRING										
WEAPON NO. 13 WITHOUT LAUNCHER										
13	—	0	-0.103	—	0	-4.56	—	—	—	—
	—	0	-0.095	—	0	-3.00	—	—	—	—
WEAPON NO. 14 WITH LAUNCHER										
14	—	0	-0.079	—	0	-5.30	—	—	—	—
	—	0	-0.095	0.237	0	-1.50	-7.40	—	—	—



(CONFIDENTIAL) FIGURE 27 DISPLACEMENT, VELOCITY, ACCELERATION VS. TIME (U)
SPRINGFIELD ARMORY SPIW SYSTEM

spring compression carefully measured from the displacement-time record and the calibration of the buffer spring. The calibration of the spring is shown in Figure 28.



(UNCLASSIFIED) FIGURE 28 LOAD - DEFLECTION CURVE
BUFFER ASSEMBLY
SPRINGFIELD ARMORY SPIW SYSTEM

The estimated forces are given as follows:

	Acceleration ft/sec^2	Force lbs
Bolt - breech impact	9.0×10^4	1540
Operating Rod - rear impact	8.5×10^4	1690
Force at unlocking	2.3×10^3	460
Bolt - rear buffer impact	1.9×10^3	370

The above forces were estimated mainly to determine the order of the forces some components of the bolt are subjected to and to form some indication of their life expectency.

The average firing pin energy for first round firing is 64 ± 4 inch-ounces. No misfired rounds were observed during this study.

Discussion

In general, the Springfield SPIW system appears well designed and, for a prototype weapon, its operation is quite good. However, there are some components which require some revision for positive operation or for increased life. These components are discussed as follows:

The Three-Round Control System. The selector mechanism is shown in Figure 29. The system is operated by an arm riding in a cam slot milled into the side of the operating rod. The arm rotates the control wheel containing six pins or studs set at intervals of 60° around the control wheel. An escapement prevents more than 60° rotation per round. After three rounds the control wheel disengages a link allowing the bolt to catch on the sear. Successive bursts may be fired by releasing, then pulling the trigger. The system contains no automatic indexing system and thus may fire only one or two rounds when a three-round burst is

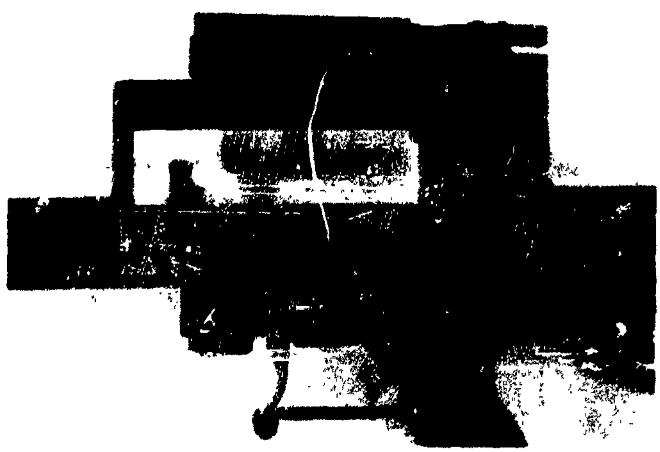


Figure 29. (CONFIDENTIAL) Mode of Fire Control Mechanism (U)

first selected. For an undetermined reason, one gun, No. 14, twice fired full automatic with the selector switch set for three-round bursts. For semi-automatic fire the control wheel disengages the sear link with the firing of each round.

The Box Feed Mechanism. A rectangular box magazine is used in the weapon. The magazine contains tandem stacks of cartridges fed upward by saw tooth springs of low stress. Feeding initially is from the forward compartment. Simultaneously with feeding of the last round in the forward compartment, a pawl attached to the rear of the bolt moves a round from the rear stack into the front compartment. This action continues until the magazine is empty at which time the operating rod is held to the rear by a sear activated by the magazine. When feeding from the front compartment, at least one round must be in the rear compartment. The rear sear can fail allowing the feed pawl to catch on the top of the magazine thus stopping the gun, damaging the magazine housing or breaking the feed pawl. Several instances of failures to feed occurred ending either with an empty chamber, an over-ride or a 12 o'clock jam. It is believed that when just a few rounds are in the front compartment, the spring force is too low for positioning of the round in the time allotted by the bolt. A stoppage occurred when a round from the rear compartment was carried forward by the feed pawl and jamed between the two top rounds in the front compartment.

The Ejector. The ejector is a spring loaded plunger projecting through the face of the bolt opposite to the extractor. When the fired cartridge case or complete round clears the chamber, the plunger is pushed forward by its relatively heavy spring pivoting the case around the extractor lip. One failure to completely eject the fired case was observed on weapon No. 14.

Barrel Vibration. The vibration of the barrel is caused almost entirely by the escape of propellant gas from the top series of holes drilled in the compensator. It is much more pronounced when the rifle is mounted in the machine rest but is noticeable when firing from a shoulder-elbow rest position. Since the Springfield bi-pod attaches to the receiver and not the barrel, dispersion resulting from vibration could be excessive in the prone bi-pod position.

The Charging Handle. The charging handle is assembled in a T-slot milled in the forward end of the operating rod and is held in position by a plunger which meshes into a hole drilled vertically into the slot. The plunger is restrained from lifting by a spring loaded detent. When the operating rod hits the buffer the flexural force created pops the plunger free of the hole. When the bolt hits the breech, the handle flies forward and is ejected from the operating rod. This misaligned buffing force has also resulted in cracked operating rods.

The Automatic Area Round Launcher Single rounds followed by two dummy rounds were loaded. Several misfired rounds were obtained because of a stuck firing pin. The energy contained in the hammer and hammer spring appears quite low. The box magazine was awkward and difficult to insert in the launcher because of a lack of some positive simple means of holding the rounds in the magazine.

Resumé

The Springfield SPIW system has a "Bull Pup" appearance with a straight stock and high sights which make accurate aiming somewhat difficult. The balance is good because the bulk of the mechanism is assembled in the butt stock and because of the location of the launcher. The barrel is relatively long with a considerable portion unsupported. The muzzle fixture, a combination flash hider, muzzle brake and compensator, together with the gas operating system produce excessive bending and vibration of the barrel. The buffing forces are not properly applied to the moving parts. Cracked operating rods, broken extractors and broken plastic triggers have occurred. Failures in some components of the prototype weapons are expected but can be corrected by minor design changes. The three-round control mechanism because of its cam control should be safe and positive in operation. The control mechanism does not contain an automatic three-round reset. The tandem magazine has considerable advantage over the drum magazines even though it is not fully developed. In general, the weapon is well designed and appears to have sufficient ruggedness for military use. In view of the observations made during the investigation of the Springfield SPIW system, the following is suggested:

1. Investigate and revise the three-round control system to eliminate any chance of full automatic fire at this setting or full automatic fire if breakage occurs in the control system.

2. Investigate and revise the box magazine and feeding pawl to prevent interference between pawl and magazine or pawl and round. Also increase the spring tension to decrease the positioning time of the round to well below the time allotted by the bolt.

3. Further investigate the functioning of the ejection system.

4. Strengthen or revise the extractor to eliminate breakage.

5. Redesign the box feed for the area round to ease loading.

6. Spread the buffing load over a greater area of the operating rod-bolt carrier combination so that the motion is more directly opposed.

(CONFIDENTIAL) WINCHESTER SPECIAL PURPOSE INDIVIDUAL WEAPON (U)
(OLIN MATHIESON CHEMICAL CORP.)

Description

The Winchester weapon system is shown in Figure 30. The weapon is gas operated and employs a floating barrel-receiver system, which has erroneously been called a soft recoil system. The rifle stock is conventional but because the mechanism is assembled low in the stock it contains some of the features and advantages of the in-line stock together with the appearance of lower rear and front sights. Ammunition is fed to the weapon from a plastic 60-round drum magazine located just ahead of the trigger.

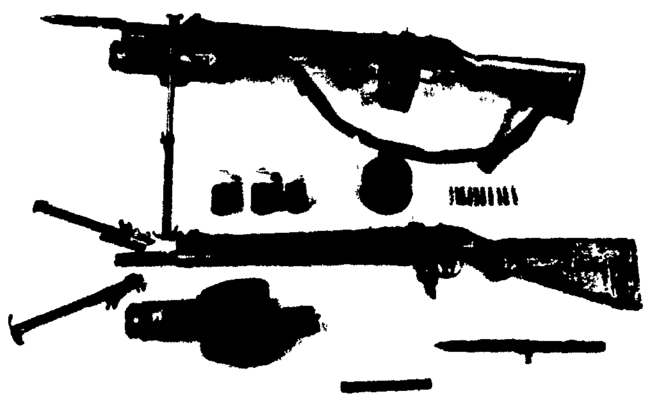


Figure 30. (CONFIDENTIAL) Winchester SPIW System (U)

The use of the floating barrel-receiver-stationary feed system requires a longer bolt travel relative to the barrel to compensate for the motion and position of the barrel at beginning of stripping of the round from the magazine. The internal parts are shown in Figure 31. The power for bolt recoil is obtained from a short gas piston which impinges on the operating rod. The operating rod has a lateral extension which serves as a camming pin for locking and unlocking the bolt and which is connected to the firing pin to complete the firing pin assembly. The driving spring has three functions: to retard the recoil of the bolt and return it to battery, as a recoil spring for the barrel and receiver during unlocking and as a dubious aid of the firing pin booster spring. A ratchet-spring friction device, located toward the muzzle and attached between the stock and barrel, operates in conjunction with the driving spring to limit the motion of the barrel and receiver. The movement of the barrel is influenced by friction in the system, by the recoil and firing pin booster springs by the cantilever spring ejector, by the muzzle device and by the gas action between barrel and operating rod.

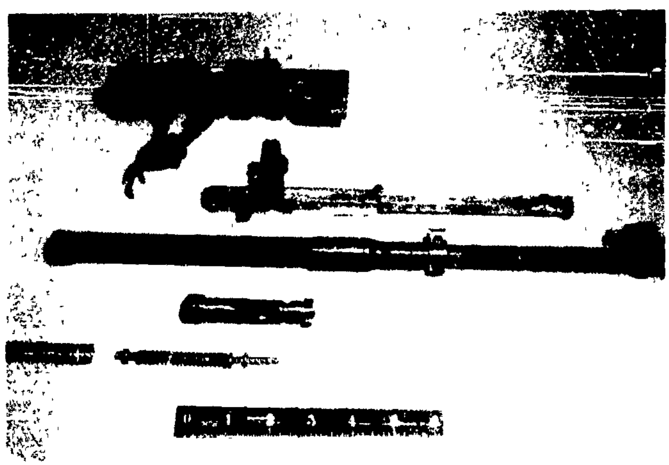


Figure 31. (CONFIDENTIAL) Barrel, Bolt and Operating Mechanism (U)

The barrel is equipped with a combination muzzle brake, flash hider and stripper retainer. The muzzle and device are shown in Figure 32. The device can be unscrewed by hand for stripper change. Threads for this are at the muzzle. The last two inches of the barrel is perforated to vent gases into the rearward portion of the muzzle device to provide braking. Gases which are not vented pass through the stripper and engage canted portions of the flash hider vanes and thus tend to keep the muzzle device screwed on. The perforations in the barrel reduce the length which is effective for attaining the desired muzzle velocity.

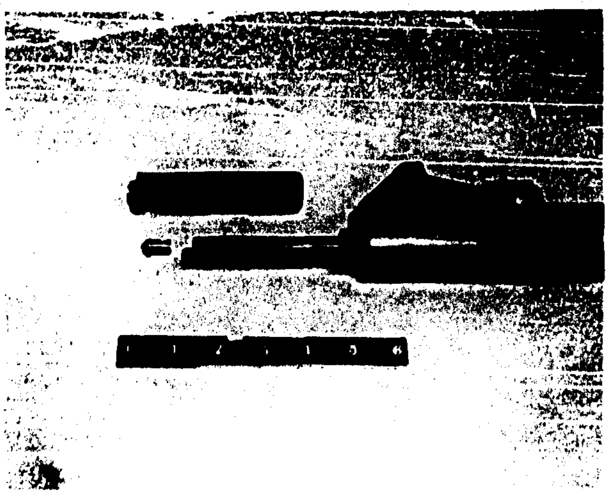


Figure 32. (CONFIDENTIAL) Muzzle, Stripper and Muzzle Brake - Flash Hider (U)

The rifle is fired from a front sear for semi-automatic fire and controlled three-round bursts. A rear sear is used for full automatic fire except that for the first round either the front or rear sear may be used. Charging the weapon is safe when the selector is set for semi-or full automatic, however if the

three-round counter wheel is not indexed the weapon will fire upon changing. This is avoided by cycling the mechanism by hand before charging until the wheel is indexed. The selector switch is not positive, allowing the indication of a semi-automatic setting while the selector is actually set for three-round bursts.

The area launcher is located near the muzzle and feeds the second and third rounds automatically from pods located on the right and left hand sides of the launcher. The launcher has a "forward recoiling" barrel to limit the length of the launcher and to operate the feeding mechanism. The launcher is attached to the forward end of the plastic stock. Since the forward section of the stock is weak in torsion, the stock can easily be damaged by the unbalanced twisting action of the launcher in firing, further resulting in extremely poor accuracy.

Procedure and Results

The weapons were mounted in a machine rest as shown in Figure 33. The soft rubber butt pad and pieces of neoprene rubber served to absorb the recoil forces with only a small recoil movement.

Figure 33. (UNCLASSIFIED) Mount for Bolt Motion Study

Displacement-time records of the operating rod and barrel movement were obtained from rifles, Nos. 1, 3 and 9, when firing controlled three-round bursts and bursts in full automatic fire. The conditions of firing and the malfunctions obtained are given in Table IX.

The average rates of fire obtained from each gun when mounted in the machine rest are given in Table X.

The malfunctions listed in Table IX are commonly observed in automatic weapon firings. The cause or causes for the excessive number of malfunctions obtained throughout the firing of the three Winchester weapons are explained with the explanations based largely on the data obtained and on observations made at each failure. As an aid in the explanations, two tracings of the operating rod and barrel motion as a function of time, obtained from weapon No. 3 prior to and after factory revision, are shown in Figures 34 and 35.

The operating rod and barrel motion of Figure 34 was obtained by firing three-rounds in full automatic fire using the front sear since the weapon at this time was incapable of firing controlled three-round bursts. The second tracing was obtained from a controlled three-round burst after the weapon had been reconditioned and returned from the factory.

The explanation of each kind of malfunction observed is as follows:

Failures to Feed. Three kinds of feeding failures were observed: a complete failure to strip the round from the magazine throat ending with an empty chamber, a partial stripping and over ride ending with the bolt jammed against an indented and sheared section of the cartridge forward of the groove and last, the nose of the projectile jammed against the barrel of the 12 O'clock position with the bolt open and resting against the base of the case. As shown in either Figure 34 or 35, the bolt is underpowered and its recoil cycle is short of the rear sear position. Also to be noted is the difference in time allowed for the incoming round to attain feeding position after being uncovered by the bolt. It will also be noted that the position of the barrel-receiver assembly varies with respect to the bolt face. Since the magazine is fixed and the distance the round must travel varies, the feeding path of the round varies.

TABLE IX

(CONFIDENTIAL) FUNCTIONING DATA (U)

Winchester Special Purpose Individual Weapon System

Ammunition: XM144, Lot WCC 6028

Weapon Number	Rds. Fired	Condition	Malfunctions
1	33	Machine rest controlled 3-rd. bursts and automatic fire	4-Failures to feed, over rides (short bolt travel) 10-Failures to feed, 12 o'clock jams 2-Failures to feed, gas cylinder unscrewed 1-Failure to extract 2-Failures to extract 1-Failure to eject 2-Control counter wheel failures 2-Misfired
	15	Shoulder fired	4-Misfires, 1 round deeply indented at charging on semi-automatic; sear surface worn and rounded.
	48	Rds. Fired, total	28 Malfunctions, total
3	147	Machine rest controlled 3-rd. bursts and automatic fire	10-Failures to feed, 12 o'clock jams 13-Failures to feed with empty chamber 4-Failures to feed, over rides 2-Failures to extract 3-Failures to eject 4-Control counter wheel failures 9-Failures to fire first round 4-Failures to fire succeeding rounds
	147	Rds. Fired, total	49 Malfunctions, total

TABLE IX (Cont'd)

Weapon Number	Rds. Fired	Condition	Malfunctions
9	41	Machine rest controlled 3-rd. bursts and automatic fire	6-Failures to feed, 12 o'clock jams 1-Failure to feed with empty chamber 4-Failures to feed, over rides 1-Failure to extract 1-Failure to eject 1-Failure of 3-rd. control counter wheel
	6	Shoulder fire	2-Failures to fire first round
	47	Rds. Fired, total	16 Malfunctions, total
3		After reconditioning at factory	
	17	Machine rest, recoil retarded by hand, floating barrel, automatic fire and 3-rd. bursts	1-Failure to fire first round
	1	Barrel locked forward	1-Failure to feed, 12 o'clock jam
	9	Barrel travel limited to approximately 1/2 travel	1-Failure to feed, over ride
	23	Machine rest 3-rd. bursts and automatic fire	2-Failures to extract 2-Failures to fire first round
	23	Spring-ratchet friction element disconnected	1-Failure to feed, over ride 2-Failures to fire first round 1 Light struck primer on second rd., bolt stopped forward of sear position, barrel recoiled to meet bolt.
	19	Cord pendulum mount, floating barrel	3-Failures to feed, 12 o'clock jam 3-Failures to fire first round
	33	Barrel travel limited to approximately 0.30 inch	5-Failures to fire first round
	66	3-wire pendulum, locked and floating barrel	1-Failure to feed, 12 o'clock jam 1-Failure to eject 2-Failures to extract
	115	Shoulder firing, 3-rd. bursts, locked and floating barrel	2-Failures to feed, over ride 5-Failures to fire first round 2-Failures to eject 1-Failure to extract
	306	Rds. Fired, total	36 Malfunctions, total

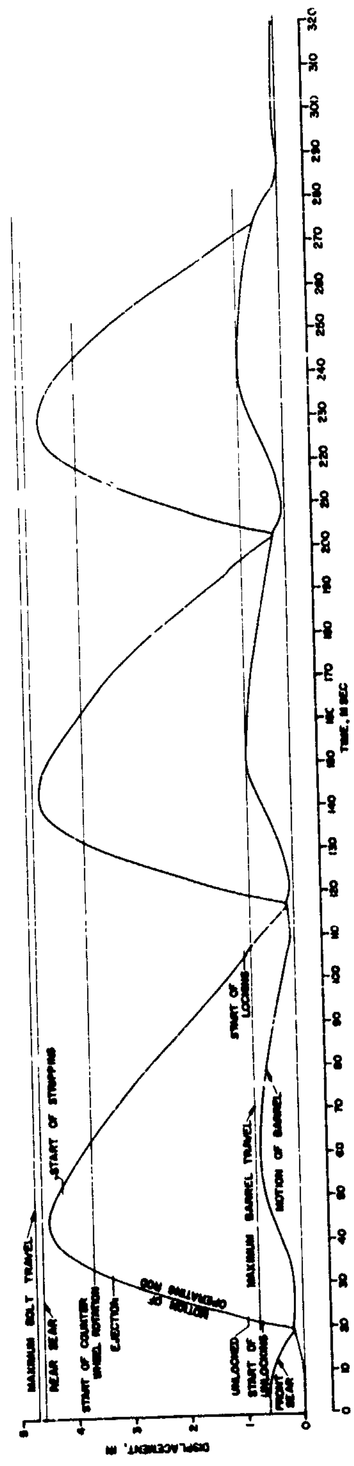
TABLE X

(CONFIDENTIAL) RATES OF FIRE, MACHINE REST (U)

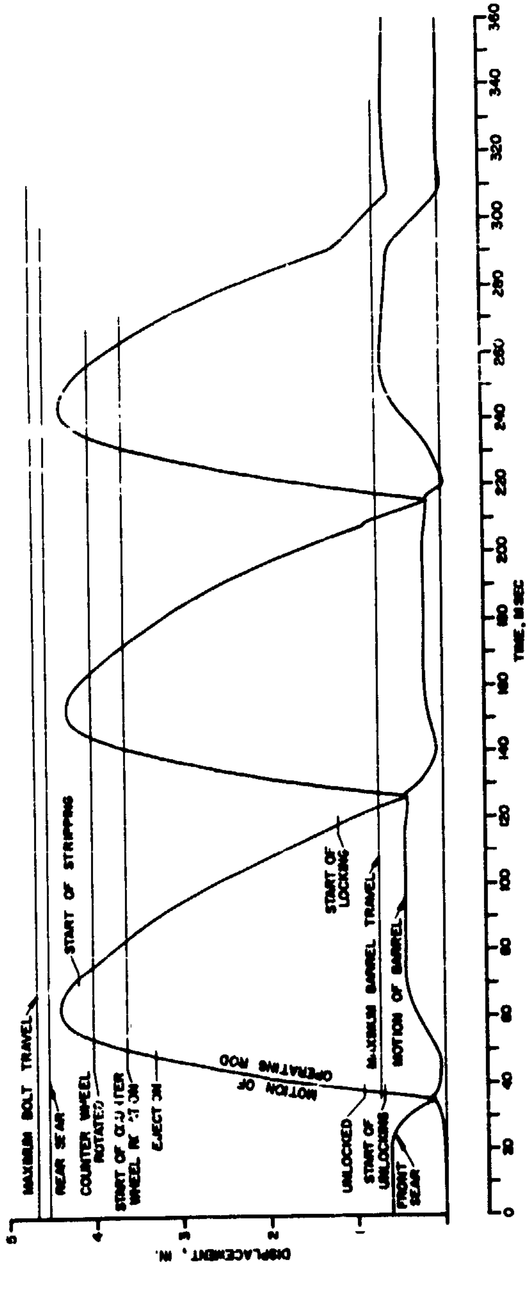
WINCHESTER SPECIAL PURPOSE INDIVIDUAL WEAPON SYSTEM

AMMUNITION: XM 144, LOT WCC 6028

Weapon Number	Three-round bursts (spm) Max	Av	Min	Automatic Fire No. of Rds. Fired	(spm) Max	Av	Min
1	653	643	633	3	721	718	715
	656	648	640	8	734	704	686
	660	652	645				
3	679	657	634	12	786	734	638
	785	629	573	13	817	790	775
	661	631	600	8	866	830	788
				12	784	734	639
9	641	640	638	3	765	745	727
	629	627	625	4	729	695	642
	640	632	623	9	740	717	683



(CONFIDENTIAL) FIGURE 34 DISPLACEMENT VS. TIME
3 ROUNDS AUTOMATIC FIRE
PRIOR TO FACTORY REVISION (U)
WINCHESTER SPIW SYSTEM



(CONFIDENTIAL) FIGURE 35 DISPLACEMENT VS. TIME
CONTROLLED 3 ROUND BURST
OBTAINED AFTER FACTORY REVISION (U)
WINCHESTER SPIW SYSTEM

Returning to the three kinds of malfunctions, the first two mentioned are caused by insufficient time for positioning the round to be fed. The positioning time is a function of bolt recoil distance and friction in the magazine. The third feeding malfunction is caused by the variable distance between bolt face and breech with insufficient round guidance to obtain positive feeding. In general, it is suspected that the nose of the round dropped, hit the breech or portion of plastic stock and was deflected upward to stub at the 12 O'clock position.

A total of 63 failures to feed were observed in the firing of 548 rounds. Approximately 50% (3 malfunctions) are chargeable to the low force provided by the magazine for positioning the rounds and 50% (32 malfunctions) chargeable to the varying feeding path.

Failure to Extract. In general, failures to extract are caused by the extractor losing its grip on the cartridge case. The extractor spring of the Winchester rifle is weak and poorly designed. However, what appeared to be a failure to extract occured which actually involved short bolt travel coupled with almost maximum barrel-receiver travel and lack of ejector impact.

Failure to Eject. In general, failures to eject have been caused by the fired case hitting the rear of the ejection port and bouncing back into the path of the bolt. It is quite possible that the variable relative position between barrel-receiver and bolt could cause a lighter ejector impact than was required to rotate the case out of the path bolt.

Failure of the Three-Round Control System. When set for controlled three-round bursts, a lever is lifted from a notch cut into the control wheel enabling the wheel to rotate. When the first round is fired, a spring loaded pawl contained in the operating rod hits one of three studs on the control wheel and rotates it 120°. The wheel is restrained in this position by a spring riding on a triangular cam milled on the hub of the control wheel and by a projection on the pawl which extends forward. After rotating the wheel into the second-round position, the bolt and operating rod continue recoiling until all energy is absorbed by the driving spring and the spring in the operating rod. Thus the pawl-operating rod spring becomes another recoil spring. In automatic fire, the control wheel is locked against rotating and the operating rod spring is compressed an additional 0.4 inch. In this manner the bolt recoil distance is shorter and the rate of fire higher.

The control wheel soon became loose because of its poor bearing structure, the cam control spring became displaced and the wheel stuck allowing the gun to fire automatically without control. After replacement of the wheel and providing more positive bearing support he operation of the three-round control system was much improved, but did not eliminate the hazard of firing one or two rounds upon charging when not properly indexed.

Failures to Fire. Misfired rounds on the first round of a burst or single shot are caused by a series of events which contribute to the low energy delivered to the primer by the firing pin. The firing pin spring is composed of the driving spring which rests on an extension of the firing pin and the booster spring which is contained in the bolt body. When released the firing pin starts forward partially unloading the initial force of the driving spring and since the booster spring is stronger than the driving spring and bears against both the firing pin and against the barrel-receiver through the bolt lock, the booster spring drives the receiver-barrel-bolt assembly rearward as shown in either Figure 34 or 35.

The energy of the firing pin was calculated by the tangent method from the velocity of both the firing pin and barrel-receiver at the point of primer impact. The energy delivered to the primer obtained in this method varies from 35 to 60 inch-ounces. Both fired and misfired primers have been observed within this range of energy. It has been established at other agencies that the energy for 100% firing is 48 inch-ounces.

Several instances of very light struck primers occurred later than the first round. In this instance the firing pin stopped forward of the front sear position and met the barrel-receiver as it drifted rearward. The ensuing impact on the primer was very light. Normally the energy for primer ignition when firing from the rear sear, or in rounds other than the first, is more than twice that required for 100% firing. Misfired rounds have accounted for approximately 30% of the total malfunctions, second only to the feeding malfunctions.

Following the first phase of the evaluation, the three guns were returned to the factory for parts replacement and general inspection. While there, a clearance was ground on the stock immediately below the breech at the 6 O'clock position to eliminate the stubbing of rounds. The firing pin booster springs and extractor springs were replaced, the control wheel revised and all parts smoothed up and

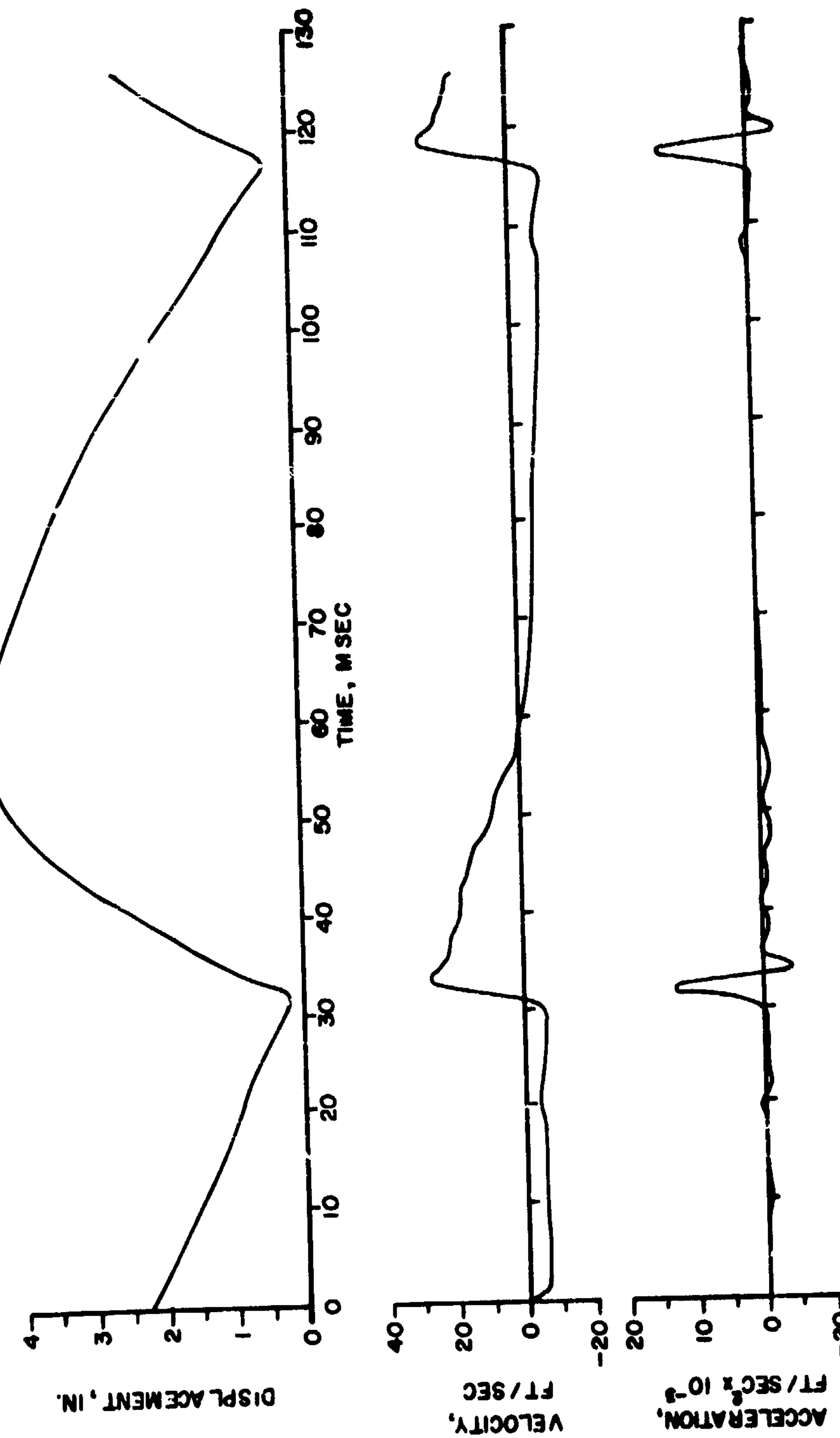
thoroughly inspected. One gun, No. 3, was returned to the Ballistics Research Laboratories. This gun was again fired for bolt and barrel-receiver motions and fired from pendulum mounts and from the shoulder to determine the advantage of the floating-barrel principle. The malfunctions per round during these firings of gun No.3, dropped from approximately 33% previous to revision to approximately 12% after revision. A typical displacement-time record was differentiated to obtain the velocities and accelerations occurring during the operating rod cycle. A plot of the results so obtained are shown in Figure 36.

The velocities as indicated in Figure 36 are substantially the same as those for the same round calculated by the tangent method. However the accelerations either are almost totally missing or are relatively below those calculated by other methods. For example, the acceleration at impact of the operating rod in battery is practically non-existant. The lack of acceleration at rapid changes in velocity from negative to positive direction are the result of the differentiation formula which is better adapted for more gradual changes in velocity with respect to time.

By using the tangent method and estimating the time between the points of tangency, the accelerations and acceleration forces are estimated as follows:

	Acceleration ft/sec^2	Force lbs
Impact of Bolt on Breech	36.3×10^3	550
Unlocking Acceleration	21.0×10^3	-

The force exerted on the bolt components when picked up and accelerated rearward by the operating rod is difficult to estimate since the frictional force between the cartridge case and chamber is most difficult to estimate. However, since the camming of, bolt is almost instantaneous, the acceleration should be quite large. The life of the extractor which must bear the acceleration force is dependent to a large degree on the force required to extract the fired case in an extremely short time.



(CONFIDENTIAL) FIGURE 36 DISPLACEMENT, VELOCITY, ACCELERATION VS. TIME (U)
WINCHESTER SPIW SYSTEM

The momentum (FT = MV) transmitted from the stock to the shoulder in a large measure determines the rise of the muzzle and consequent dispersion of the weapon. The total momentum, minus that produced by the effects of bore friction, the effects at the muzzle and the friction in the mechanism, is transmitted to the shoulder by the driving spring in parallel with the operating rod spring after the control wheel is contacted and through friction of the barrel slides and the ratchet friction element between the barrel and forward section of the stock. The advantage of a floating barrel consists of having the momentum developed during the period the bolt is locked, not delivered directly to the stock but, delivered through the recoil springs to the stock along with the remainder of the momentum developed. This delays the attainment of the usual levels of velocity of the stock and thus results in less displacement in a given period of time. However, if upon the return-to-battery of the bolt, the barrel is not attached to the stock, the full advantage of the forward impact is lost. This forward impact imparts a quantity of forward momentum equal to about half of that imparted through the recoil spring to the stock by the bolt. The displacement reached by the stock, at the time the next projectile leaves the muzzle, could be as great as that of a weapon with a fixed barrel.

As a check on the advantage of the floating barrel, the Winchester weapon was suspended by parallel pairs of strings as shown in Figure 37. It was fired with the barrel floating and with the barrel locked to the stock.

Figure 37. (UNCLASSIFIED) Weapon Suspended by Strings for Free Recoil Study

A drum camera was focused on reflectors mounted on the operating rod handle and on the stock so that displacement-time records could be obtained of the cycling of the mechanism and the displacement of the stock in three-round bursts. A solenoid was attached to the butt so that the trigger could be pulled without imparting a net momentum to the system and a weight of six pounds was attached to the fore-grip to roughly represent the mass of the man in such systems. To lock the barrel to the stock, bushings were put on the barrel between the muzzle device, front barrel slide and the gas port assembly. These bushings held the barrel 0.4 inch rearward of the normal position to make feeding of rounds possible. Three three-round bursts were fired for each of the two conditions. Displacement-time records from the two conditions are superimposed in Figure 38.

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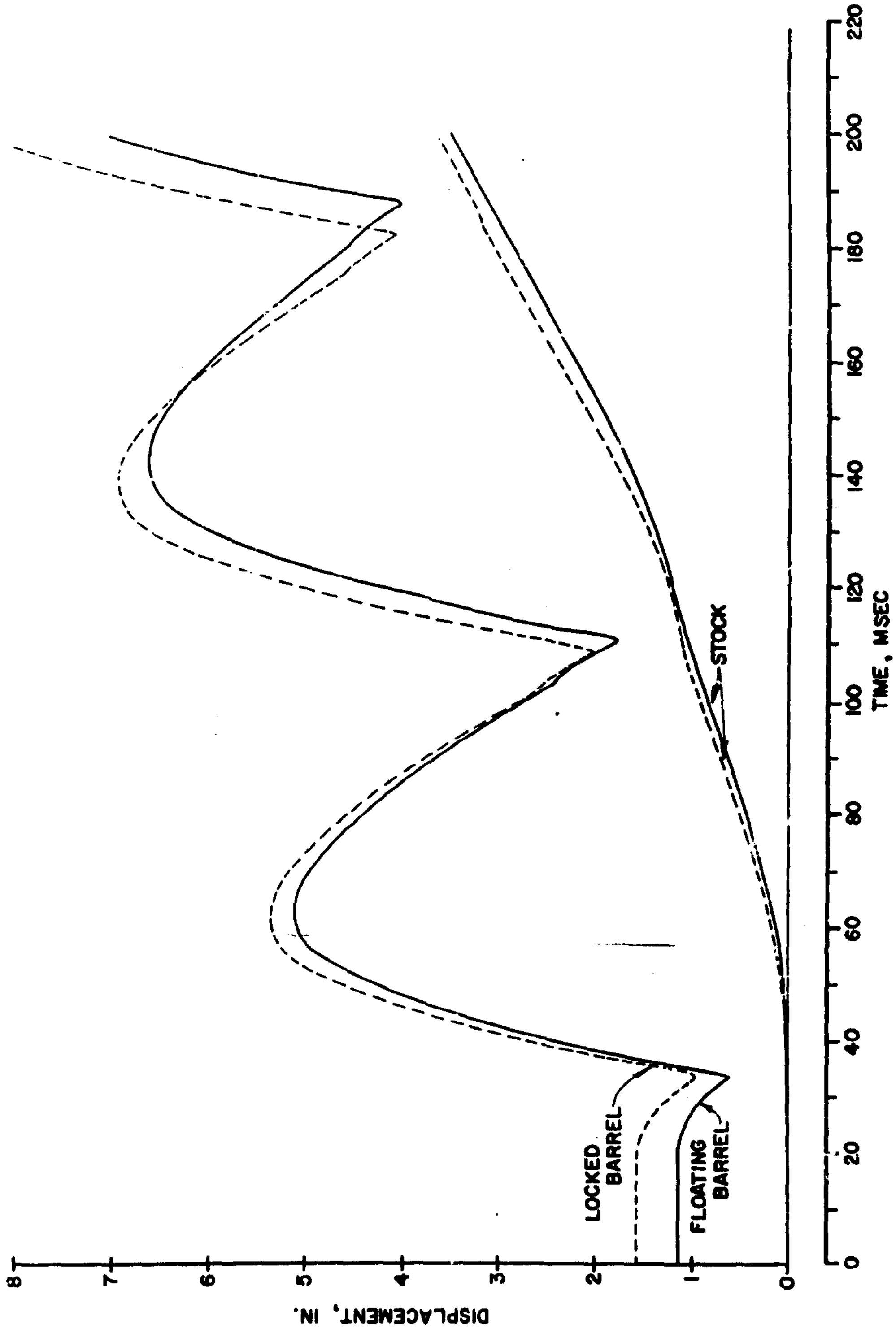
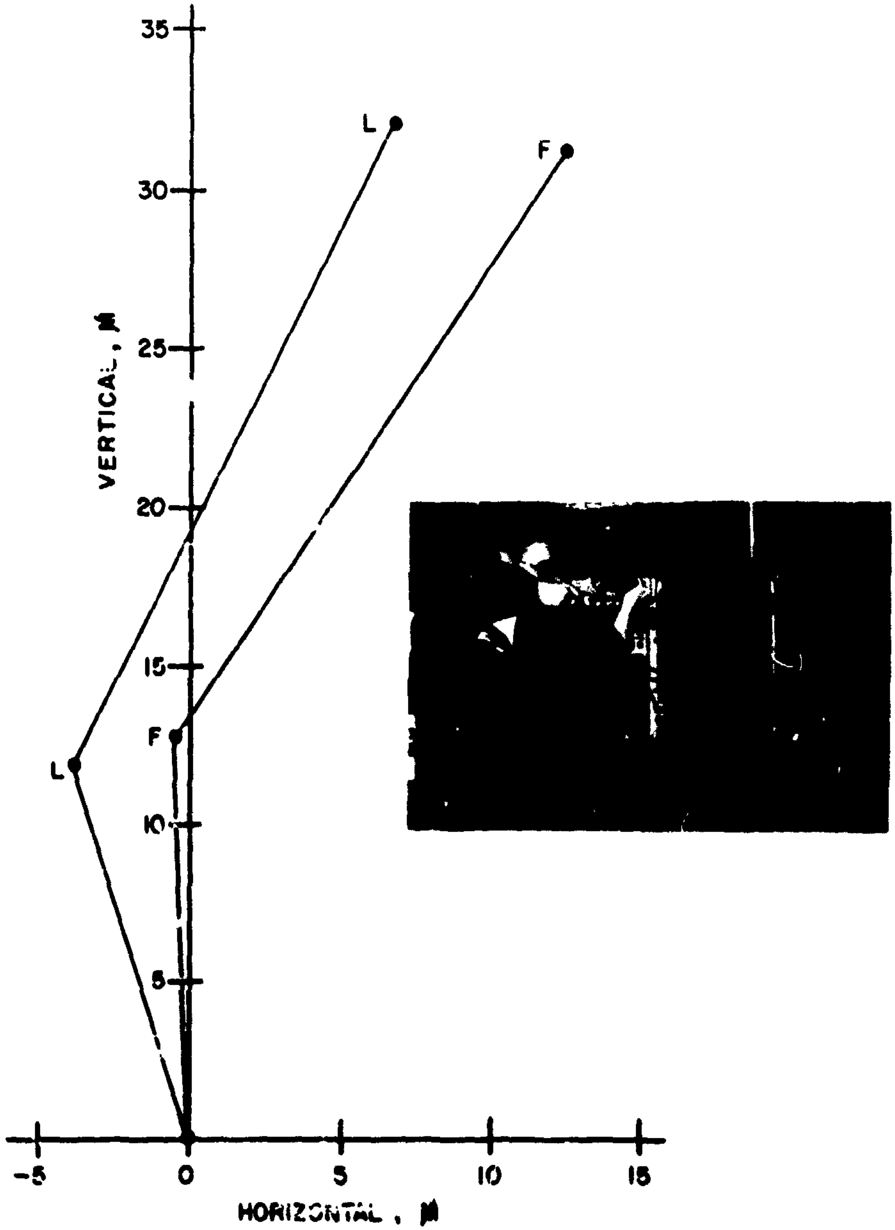


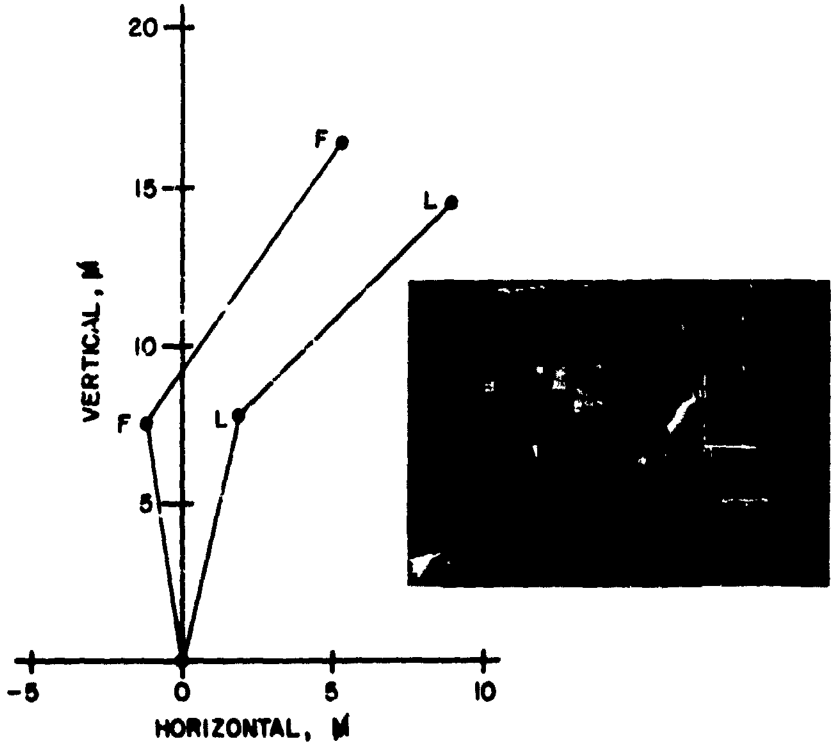
(CONFIDENTIAL) FIGURE 38 FREE RECOIL DISPLACEMENT VS TIME (U)
WINCHESTER SPIW SYSTEM

CONFIDENTIAL

To corroborate these results, and to remove any doubt concerning the reality of the test conditions, the weapon was hand held and fired in the standing position with and without the barrel locked. Two stances were used, the standard off-hand (loose) and the combat (tight). The firer was a match competitor chosen for his ability to reproduce his stance and thereby his burst target patterns. Three or more bursts of three rounds were fired for each of the four conditions. The average of the results of the loose shooting is shown in Figure 39 and of the tight shooting in Figure 40.



(CONFIDENTIAL) FIGURE 39 AVERAGE TARGET PATTERNS (U)
WINCHESTER SPIW SYSTEM
3 ROUND BURSTS LOOSE SHOOTING
L- LOCKED BARREL F-FLOATING BARREL



(CONFIDENTIAL) FIGURE 40 AVERAGE TARGET PATTERNS (U)
WINCHESTER SPIW SYSTEM
3 ROUND BURSTS TIGHT SHOOTING
L - LOCKED BARREL F-FLOATING BARREL

In both the loose and tight stances there is no significient difference between having the Winchester barrel locked or floating.

Resumé

The Winchester SPIW system has a conventional appearance with drop stock and low sights for easy aiming, but is muzzle heavy because the area round launcher is located near the muzzle. The floating barrel principle offers no advantage over the same weapon having a fixed barrel with a muzzle brake flash hider attachment. Because of its floating barrel characteristics, an inordinate number of failures to feed, failures to eject and failures to fire first rounds have been obtained. The plastic drum magazine contains excessive friction and low forces for positioning rounds. all of which contribute to the many feeding failures. The three-round control system is relatively simple but in its simplicity is unsafe unless unusual precautions are observed. An over all assessment of the weapon indicates that a major redesign is required to obtain positive functioning and to meet the requirements imposed by the SPIW program.

As a result of the evaluation of the Winchester rifle two alternatives are offered. These alternatives are either (1) abandon the Winchester system, or (2) allow a major redesign. If a major redesign is allowable, the following is suggested:

1. Abandon the floating barrel-receiver design and attach the mechanism rigidly to the stock and incorporate a muzzle brake-flash hider-compensator attachment.

This design will then be similiar in most respects to other weapons considered in the SPIW program.

2. Design a simple well-tuned soft recoil mechanism containing a magazine fixed with respect to the mechanism and a spring-friction recoil system between the mechanism and stock. The recoil system should be so tuned that the forward momentum of the mechanism, after the first round, will partially counteract the rearward momentum produced by firing the second or any succeeding round. Although this will involve a movable feed mechanism and muzzle attachments, it is a good way in which the transfer of momentum from the rifle to the shoulder may be reduced. Together with the soft recoil system the mechanism must be redesigned to eliminate all objectional features of the present design, i.e., to obtain positive feeding and ejection, controlled three-round bursts with automatic re-indexing and sufficient firing pin energy for positive primer ignition.

ACKNOWLEDGMENT

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S. S. Lenz
S. S. LENZ

Richard F. Cronin
R. F. CRONIN

W. M. Werner
W. M. WERNER

APPENDIX

(CONFIDENTIAL) TABLES OF MEASUREMENTS (U)

Table XI - Components of Impulse

Listed are values of the components of impulse along the bore line (recoil) and perpendicular to the bore line at the muzzle device, both downward and leftward. Also included is the standard deviation (σ) for each measurement and the number (n) of rounds fired in the ballistic pendulum to obtain it.

Table XII - Rates f Fire

Listed is the average rate of fire for each of the prototype weapons in full automatic fire (FA) and controlled bursts of three rounds (3RB). Included are the number (n) of determinations and the standard deviation (σ).

Tables XIII through XVIII - Physical Measurements

Listed for each of the weapons are the weights, linear measurements and moments of inertia of various combinations of components. These are designated as follows:

R	rifle w/magazine, w/o fore-grip if replaced by launcher
r	round of appropriate ammunition
A	rea round
Rcg	radial distance from center of butt plate to center of gravity
Ycg	distance from center line of bore to center of gravity
Icg	moment of inertia about a horizontal axis through the center of gravity and perpendicular to the center line of the bore
Ibp	moment of inertia about a horizontal axis through the center of the butt plate and perpendicular to the center line of the bore
DNA	does not apply
MBC	muzzle-brake and compensator

Launcher includes launcher magazine and sights.

TABLE XI

(CONFIDENTIAL) COMPONENTS OF IMPULSE (U)

				IMPULSE (lb - sec)		
Weapon	Ammunition	Condition	n	Recoil	Downward	Leftward
M14	WCC 6007	Normal	10	2.632 σ = 0.012	- -	DNA
M16	RA 5027	Normal 18 Mar 64	10	1.200 σ = 0.015	- -	DNA
		Normal 27 Mar 64	10	1.247 σ = 0.012	- -	DNA
M16MBC	RA 5027	MBC	10	0.959 σ = 0.008	0.140 σ = 0.003	DNA
AAI	AAI-650-15	Normal	8	0.426 σ = 0.048	0.078 σ = 0.003	- -
	WCC 6002	Normal	10	0.448 σ = 0.006	0.080 σ = 0.002	- -
	AAI-650-14	MBC rotated 90°	10	0.459 σ = 0.006	- -	0.006 σ = 0.002
SPR	WCC 6028	Normal	10	0.410 σ = 0.005	0.049 σ = 0.002	- -
		MBC rotated 90°	10	0.411 σ = 0.006	- -	0.005 σ = 0.002
WLN	WCC 6028	Rifle	10	0.466 σ = 0.004	DNA	DNA
		Rifle w/ launcher	10	0.464 σ = 0.004	0.022 σ = 0.004	DNA
Area round SPR single shot launcher			10	2.830 σ = 0.028	DNA	DNA

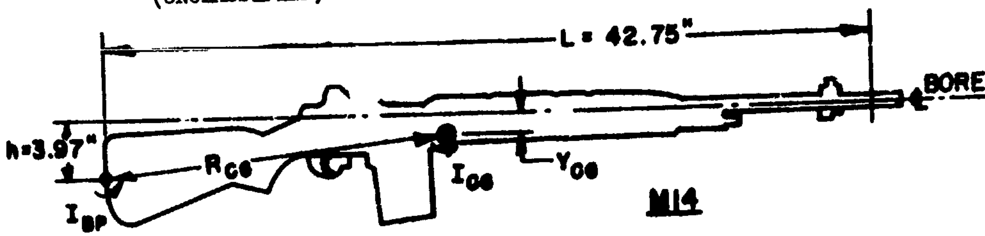
TABLE XII

(CONFIDENTIAL) RATES OF FIRE (U)

Weapon system	Weapon number	Rate of fire (spm)					
		3RB	σ	n	FA	σ	n
AAI	2	2184	238	4	700	6	28
	3	2360	67	4	690	13	27
	4	1869	140	6	713	57	15
SPR	11	1621	30	6	1597	32	23
	14	1663	78	8	1694	51	10
	15	1709	44	10	1741	53	21
	17	1684	82	8	1618	42	20
	19	1632	30	4	1617	30	27
WIN	1	647	10	6	709	19	9
	3	637	-	2	769	33	22
	9	626	8	6	707	25	10

TABLE XIII

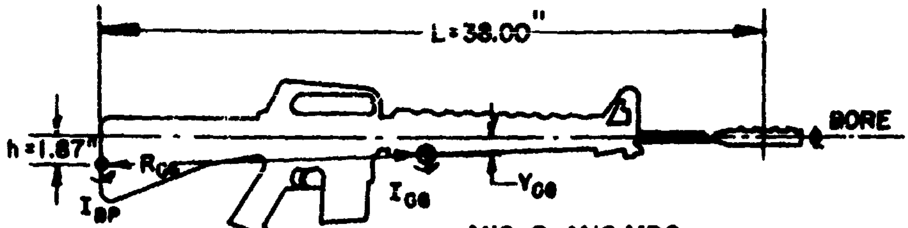
(UNCLASSIFIED) PHYSICAL MEASUREMENTS



	M14
Weight (lbs.)	**Foregrip**
R	9.24
R + 10r	9.78
R + 20r	10.32
R_{cg}(in.)	
R	19.56
R + 10r	19.47
R + 20r	19.34
Y_{cg}(in.)	
R	1.067
R + 10r	1.125
R + 20r	1.250
I_{cg}(lb-ft-sec^2)	
R	0.220
R + 10r	0.221
R + 20r	0.222
I_{bp}(lb-ft-sec^2)	
R	0.982
R + 10r	1.021
R + 20r	1.054

TABLE XIV

(UNCLASSIFIED) PHYSICAL MEASUREMENTS

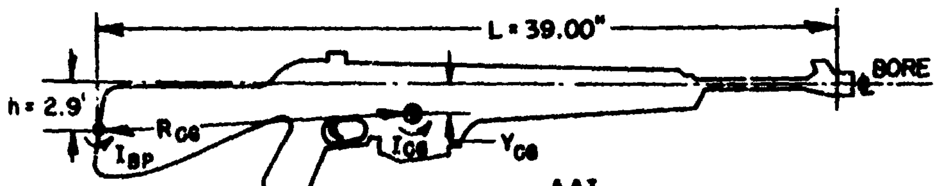


M16 & M16 MBC

	M16	M16 MBC
Weight (lbs.)		
R	6.46	6.60
R + 10r	6.71	6.85
R + 20r	6.96	7.10
R_{cg} (in.)		
R	17.66	18.12
R + 10r	17.56	17.99
R + 20r	17.50	17.92
Y_{cg} (in.)		
R	0.43	0.42
R + 10r	0.48	0.48
R + 20r	0.56	0.57
I_{cg} (lb-ft-sec^2)		
R	0.122	0.136
R + 10r	0.123	0.137
R + 20r	0.123	0.138
I_{bp} (lb-ft-sec^2)		
R	0.556	0.603
R + 10r	0.569	0.615
R + 20r	0.583	0.630

TABLE XV

(CONFIDENTIAL) PHYSICAL MEASUREMENTS (U)

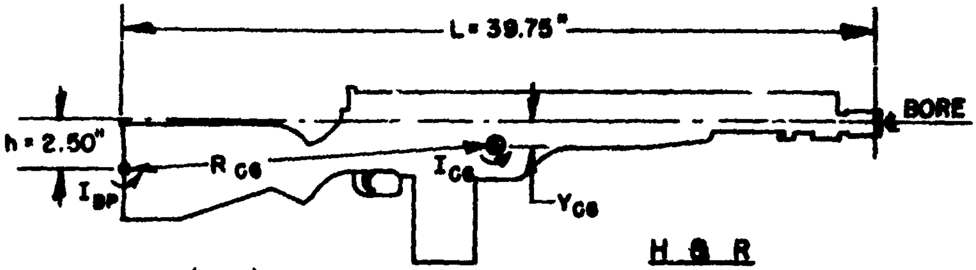


AAI

Weig' (lbs.)	Foregrip	Launcher
	0.58 ± 0.06	5.11 ± 0.03
R	6.43 ± 0.06	10.97 ± 0.04
R + 30r	6.85 ± 0.06	11.39 ± 0.04
R + 60r	7.27 ± 0.06	11.81 ± 0.04
R + 60r + 3A	DNA	13.28 ± 0.04
R_{cg} (in.)		
R	17.91 ± 0.08	22.61 ± 0.02
R + 30r	17.91 ± 0.08	22.43 ± 0.02
R + 60r	17.91 ± 0.08	22.30 ± 0.03
R + 60r + 3A	DNA	22.78 ± 0.06
Y_{cg} (in.)		
R	0.82 ± 0.04	1.10 ± 0.02
R + 30r	0.89 ± 0.04	1.13 ± 0.02
R + 60r	0.95 ± 0.04	1.17 ± 0.02
R + 60r + 3A	DNA	1.22 ± 0.02
I_{cg} (lb-ft-sec^2)		
R	0.113 ± 0.001	0.215 ± 0.001
R + 30r	0.113 ± 0.001	0.216 ± 0.001
R + 60r	0.114 ± 0.001	0.219 ± 0.001
R + 60r + 3A	DNA	0.229 ± 0.001
I_{bp} (lb-ft-sec^2)		
R	0.558 ± 0.014	1.425 ± 0.004
R + 30r	0.587 ± 0.009	1.454 ± 0.004
R + 60r	0.617 ± 0.010	1.484 ± 0.002
R + 60r + 3A	DNA	1.714 ± 0.013

TABLE XVI

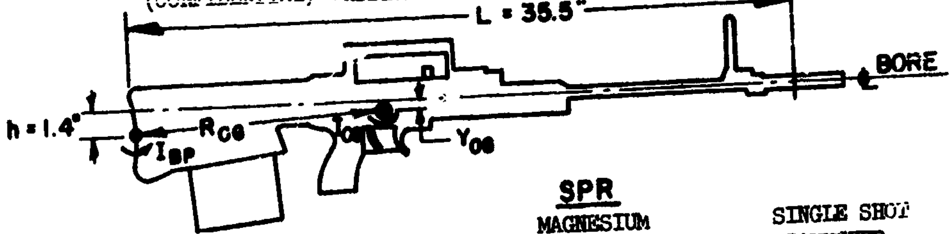
(UNCLASSIFIED) PHYSICAL MEASUREMENTS



	FOREGRIP	H & R LAUNCHER
Weight (lbs.)		
	0.4	5.3
R	15.0	19.9
R + 30r	—	—
R + 60r	—	—
R + 60r + 3A	DNA	22.0
R_{cg} (in.)		
R	—	—
R + 30r	—	—
R + 60r	—	—
R + 60r + 3A	DNA	21.5
Y_{cg} (in.)		
R	—	—
R + 30r	—	—
R + 60r	—	—
R + 60r + 3A	DNA	1.5
I_{cg} (lb-ft-sec^2)		
R	—	—
R + 30r	—	—
R + 60r	—	—
R + 60r + 3A	DNA	0.33
I_{bp} (lb-ft-sec^2)		
R	—	—
R + 30r	—	—
R + 60r	—	—
R + 60r + 3A	DNA	2.52

TABLE XVII

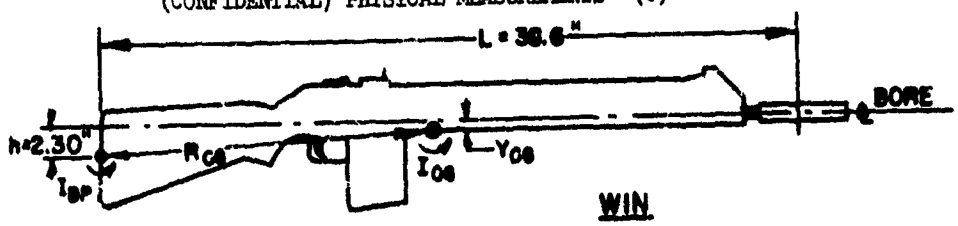
(CONFIDENTIAL) PHYSICAL MEASUREMENTS (U)



	FOREGRIP	SPR MAGNESIUM LAUNCHER	SINGLE SHOT LAUNCHER
WEIGHT (Lbs)			
	0.34 ± 0.01	4.46	1.91
R	7.71 ± 0.03	11.83	9.28
R + 30r	8.10 ± 0.03	12.22	9.67
R + 60r	8.49 ± 0.03	12.61	10.06
R + 60r + 3A	DNA	14.08	10.55
R_{cg} (in.)			
R	13.36 ± 0.05	16.73	14.42
R + 30r	12.88 ± 0.05	16.40	14.06
R + 60r	12.53 ± 0.05	16.01	13.67
R + 60r + 3A	DNA	17.17	-
Y_{cg} (in.)			
R	0.26 ± 0.02	0.75	0.50
R + 30r	0.40 ± 0.01	0.80	0.60
R + 60r	0.51 ± 0.01	0.85	0.70
R - 60r + 3A	DNA	-	-
I_{cg} ($lb\text{-}ft\text{-}sec^2$)			
R	0.137 ± 0.002	0.215	0.153
R + 30r	0.144 ± 0.003	0.219	0.160
R + 60r	0.150 ± 0.001	0.233	0.169
R + 60r + 3A	DNA	0.255	-
I_{bp} ($lb\text{-}ft\text{-}sec^2$)			
R	0.433 ± 0.005	0.928	0.568
R + 30r	0.433 ± 0.003	0.927	0.571
R + 60r	0.437 ± 0.004	0.929	0.574
R + 60r + 3A	DNA	1.151	-

TABLE XVIII

(CONFIDENTIAL) PHYSICAL MEASUREMENTS (U)



	FOREGRIP	LAUNCHER
WEIGHT (LBS)		
	0.15 ± 0.01	3.22 ± 0.01
R	7.18 ± 0.03	10.25 ± 0.03
R + 30r	7.57 ± 0.03	10.64 ± 0.03
R + 60r	7.96 ± 0.03	11.03 ± 0.03
R + 60r + 3A	DNA	12.50 ± 0.03
R_{cg} (in.)		
R	18.36 ± 0.05	22.31 ± 0.03
R + 30r	18.20 ± 0.05	22.06 ± 0.04
R + 60r	18.05 ± 0.05	21.81 ± 0.03
R + 60r + 3A	DNA	22.95 ± 0.05
Y_{cg} (in.)		
R	0.32 ± 0.02	0.67 ± 0.03
R + 30r	0.46 ± 0.02	0.76 ± 0.02
R + 60r	0.57 ± 0.02	0.82 ± 0.03
R + 60r + 3A	DNA	0.88 ± 0.02
I_{cg} (lb-ft-sec^2)		
R	0.152 ± 0.001	0.249 ± 0.001
R + 30r	0.153 ± 0.001	0.254 ± 0.001
R + 60r	0.154 ± 0.001	0.259 ± 0.002
R + 60r + 3A	DNA	0.286 ± 0.002
I_{bp} (lb-ft-sec^2)		
R	0.674 ± 0.001	1.350 ± 0.004
R + 30r	0.694 ± 0.003	1.371 ± 0.005
R + 60r	0.713 ± 0.003	1.390 ± 0.004
R + 60r + 3A	DNA	1.705 ± 0.007

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